JOURNAL
OF
THE FRANKLIN INSTITUTE
DEVOTED TO SCIENCE AND THE MECHANIC ARTS

VOL. CLXXV FEBRUARY, 1913 No. 2

RECENT DEVELOPMENTS IN STEAM TURBINES.*

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INTRODUCTORY.

CLOSE association with the more recent developments in steam turbine design and construction has fixed firmly in the writer's mind the necessity for a good understanding of the fundamental scientific principles involved, together with extended intelligent experimental investigation, in order that successful and economical operation, now demanded, may obtain, and that the future may keep pace with that advancement in the art which has been accomplished in the last decade.

Development in any art or science is advanced in proportion to the proper understanding of its principles and an intelligent co-operation and application on the part of those who use such art or science experimentally and commercially.

The more widely the principles of turbine design, construction, and operation are disseminated and understood, with the proof of such principles experimentally, the more rational will be the use of this prime mover commercially and the more rapidly and highly developed will its structure become.

* Presented at the meeting of the Mechanical and Engineering Section held Thursday, December 5, 1912.

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The purpose, therefore, of this paper is to give such fundamental principles and information on recent developments in the turbine art as are consistent with the space permissible, with the hope that those interested in the subject and associated with the development of power from steam may become better acquainted with the points which are important for reliable operation and economy and better informed on the main facts relating to the development of the steam turbine and its more recent application and performance in practice.

EARLY HISTORY.

In a manuscript by Hero of Alexandria the earliest notices of heat engines of any kind are recorded. This manuscript was probably written 150 B.C., and contains a description of a steam reaction turbine, an illustration of which is shown in Fig. 1.

From the time of Hero down to the seventeenth century, practically no record of progress in steam engines is extant.

In 1629 Branca, an Italian architect, designed a steam turbine (Fig. 2) driven by a jet of steam directed by a nozzle on vanes attached to a wheel.

Branca's wheel had all the essential parts now common to the modern impulse turbine, except it was not housed in a casing.

It is probable that if Hero and Branca had understood the laws governing steam as we know them to-day, and had had the benefit of our present knowledge of materials and tools, they would have made successful machines. The lack of such knowledge, however, delayed for centuries the development of this prime mover.

Until the end of the nineteenth century, although in the interval many steam turbines and rotary engines were patented, the reciprocating steam engine under Watts's initiative held commercially an unrestricted field and passed through many remarkable developments.

RECENT HISTORY.

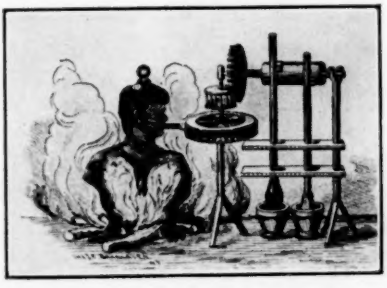
The period of experimental development of the turbine art may be said to have occurred since 1880, only after the

evolution of the modern mathematical and physical sciences, when the action of steam could be understood and the machine

FIG. 1.

Hero's turbine.

FIG. 2.



Branca's turbine.

properly designed and constructed in safe and economical forms with the aid of modern tools and materials.

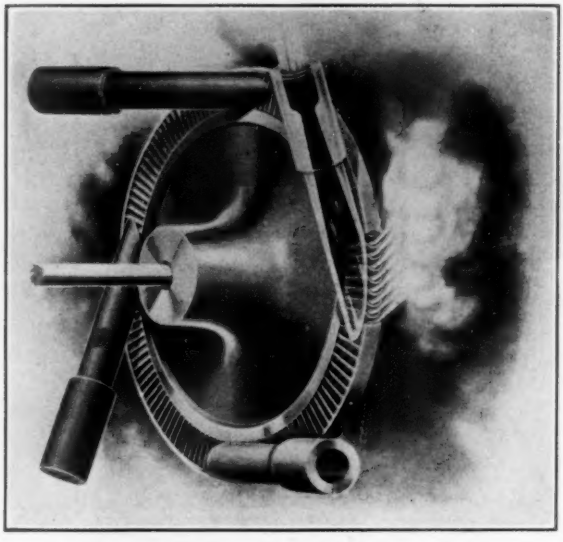
Practically nothing of value was accomplished in the turbine art until about 1882, when De Laval constructed his first steam turbine, similar in principle to Hero's reaction engine.

The economy of this machine was unsatisfactory, and for other reasons the inventor turned his attention to the development of Branca's turbine with remarkable results.

After much experimenting, De Laval developed an impulse turbine, which is still one of the standard makes (Fig. 3).

Almost contemporaneously with De Laval, C. A. Parsons,

FIG. 3.



Bucket wheel and nozzles of De Laval steam turbine.

in England, began the development of his reaction turbine, and the practicability of the design he then proposed showed that much time and thought had been given to constructive details.

Methods for reducing vibration, preventing leakage of steam, and providing for efficient lubrication contributed very largely to its success.

In his early experiments Parsons also tried a simple reaction turbine, following almost exactly the published designs of Hero. During the period from 1882 to 1903 distinct types of turbines were introduced, called, after the names of the inventors, De

Laval, Parsons, Curtis, and Rateau, all consisting, with the exception of the De Laval turbine, of a multiplicity of fundamental parts designed on the principle of simple impulse or reaction elements.

ELEMENTARY PRINCIPLES.

For a proper understanding of the sequence of events following the recent history of the turbine from 1903 to date it is necessary to comprehend the fundamental principles on which the operation of turbine engines depends. Like the steam and gas engine, the turbine is a machine for obtaining mechanical work from heat energy. A full conception, therefore, of its underlying principles requires a knowledge of pure and applied thermodynamics, as well as familiarity with mechanics and experience in machine design and construction.

The turbine converts the heat energy of a gas into useful mechanical work by transforming such heat energy into velocity and then extracting the energy in such velocity by means of the rotation of a spindle, caused by the impulse and reaction of jets of steam on suitably-designed blades or vanes.

The conversion of the heat energy of a gas involves principles in thermodynamics which for convenience have been put into Appendix I, and are a compilation of notes made by the author while tutoring at Yale.

All commercial types of turbines—steam, water, or gas—are divided into two general classes, viz., (1) impulse and (2) reaction. Strictly speaking, all steam turbines use both impulse and reaction in their operation, as the blades of the rotor are moved by the impulse and reaction of impinging jets of steam issuing from nozzles or passages essentially equivalent to nozzles.

Fig. 4 illustrates the impulse of a jet of water issuing from a vessel and impinging upon a flat board hinged opposite. As the result of the force of the jet, the board will obviously move to the right. As the jet issues from the vessel it exerts a reaction on the tank, tending to move it to the left.

Fig. 5 is intended to illustrate the significance of impulse and reaction as they are used in turbine practice. In this case water from a vessel impinges against the curved surface, as shown in the illustration, and before it leaves this surface is

turned back through an angle of 180 degrees. The board is therefore acted on by two forces simultaneously, both tending to move it to the right. The jet striking the board creates an impulse, and, when leaving the board, a reaction, both of which are equal and in the same direction, frictional losses neglected. If the jets in Figs. 4 and 5 have the same velocity and density, with friction neglected, the pressure on the block in Fig. 5 will be twice that on the block in Fig. 4.

FIG. 4.

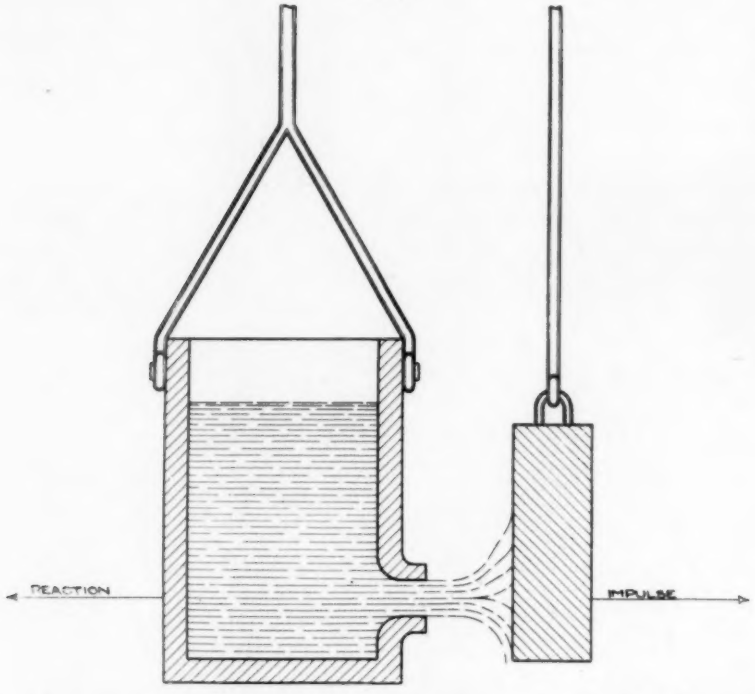


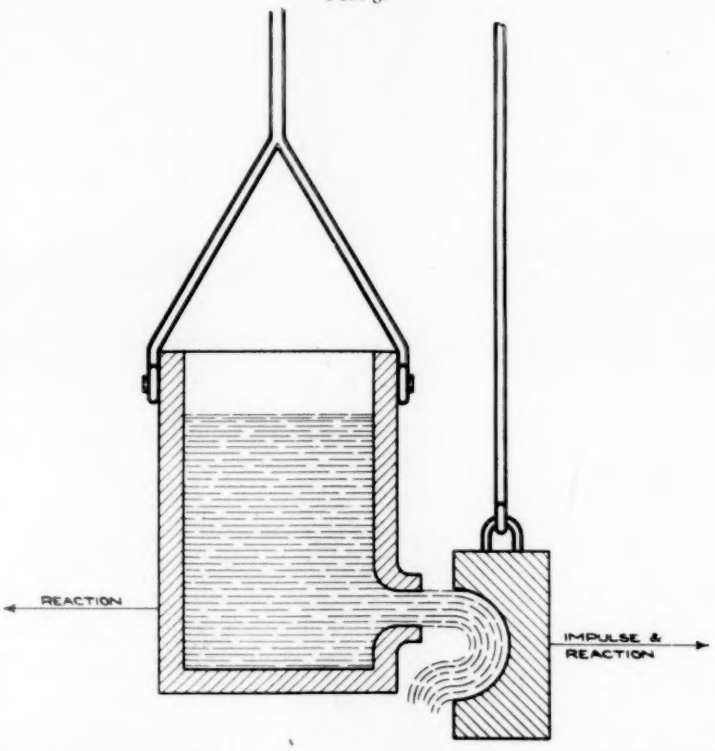
Fig. 6 illustrates a nozzle and blade wheel in which the blades have a single curvature, *i.e.*, the steam in its passage through the blades is not turned back on itself. If this wheel were held stationary the steam would leave the blades in a direction nearly parallel to the shaft. The only force, therefore, effective for moving the blades is the impulse of the jet.

Fig. 7 indicates a blade wheel and nozzle in which steam from the nozzle enters the blades in a direction parallel to the

axis, the jet then being turned backward through an angle less than 90 degrees. On leaving the blades the jet exerts a reaction on the wheel, which, if held stationary, would be felt as a force tending to turn it.

Fig. 8 shows blades with nearly 180 degrees curvature, which turn the steam back on itself on leaving the blades. The

FIG. 5.



wheel would therefore be moved first by the impulse of the jet, and then by its reaction.

It has been shown in Appendix I that when steam expands through an orifice or passage it acquires a velocity proportional to the drop in pressure which it undergoes.

In the so-called impulse turbines this expansion takes place in a fixed nozzle, and the energy of the steam, due to its velocity, is absorbed in the revolving blades of a wheel without drop in pressure through the blades themselves.

In the reaction turbine the expansion of steam takes place in the blades themselves, and the velocity of the steam caused by such expansion is converted into useful work by its reaction in leaving the blades.

As a matter of fact, all steam turbines make use of both the impulse and reaction of a steam jet acting on the blades. It is the way in which the blades are constructed and applied that distinguishes the different types of turbines, and it may be

FIG. 6.

FIG. 7.

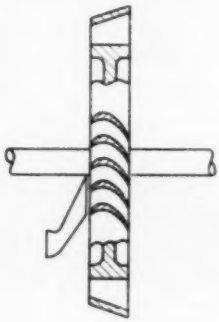
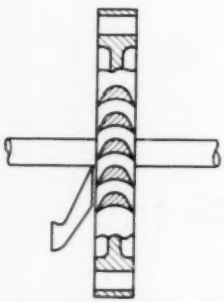


FIG. 8.



said that all impulse machines depend on the absorption of the steam velocity, due to a drop in pressure, through suitable nozzles, there being little or no pressure drop through the blades themselves; while the reaction turbine, on the other hand, utilizes the velocity of steam, caused by a drop in pressure through the blades themselves, to rotate the turbine spindle.

Compounding stages of the simple impulse or reaction element constituted the development of the turbine to 1903.

Prior to this date there were four distinctive systems in use in various countries:

First, the impulse, action, or velocity system represented by the De Laval turbine and its various modifications.

Second, the multi-stage impulse system represented by the Rateau and Zoelly turbines.

Third, the subdivided multi-stage impulse system represented by the Curtis and Riedler-Stumpf turbines.

Fourth, the reaction or pressure system represented by the various forms of Parsons turbine.

The distinctive characteristics of the impulse and reaction turbine elements lie almost entirely in the fact that in the impulse element expansion of steam is carried out within a system of nozzles, while in the reaction element expansion occurs within the blades themselves, both stationary and moving, but in successive small steps.

The function of a steam nozzle is the production of the desired velocity, while that of its corresponding blade or blades is to absorb this velocity for the production of useful work. Here the pressure drop is almost entirely confined within the nozzle and is non-appreciable through the blades.

On the other hand, in the reaction turbine there are no nozzles, the blades corresponding thereto, as noted above. In the expansion within the blades a reactive thrust is produced in the opposite direction from the issuing steam jet, which thrust forms the major part of the turning moment of the reaction turbine, and hence its classification as such. The remainder, which is but a small factor, is produced by impulse action of steam from the various stationary rows of blades.

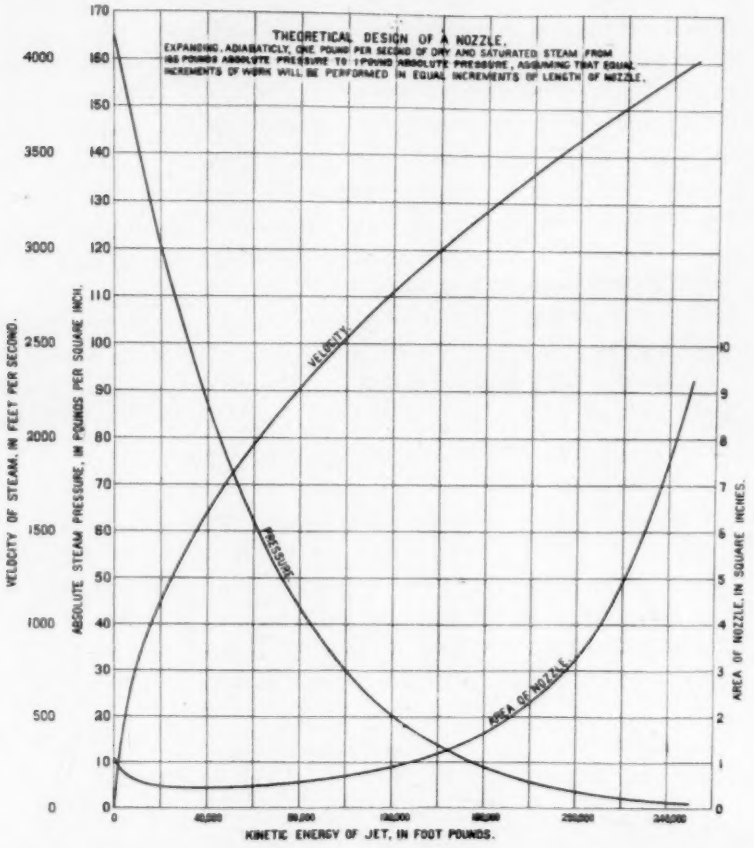
A definite relation must exist between steam velocity and blade velocity for the production of maximum efficiency.

Theoretically, in the pure impulse system the moving blades must recede at one-half the velocity of the impinging jet for maximum efficiency. In the pure reaction turbine the moving blades must recede at the same velocity as that of the steam jet in order to absorb all the velocity therein. This would appear to constitute a point in favor of the impulse system. In the reaction system the apparent objection is overcome by the simple expedient of employing more expansion stages. All

this presupposes a tangential direction of the steam jet parallel to the plane of rotation.

With side jets, such as are of necessity used in practice, it is impossible to obtain a complete reversal of the jet, and hence a part of the jet velocity is unavailable.

FIG. 9.


THEORETICAL DESIGN OF A NOZZLE.
EXPANDING ADIABATICLY, ONE POUND PER SECOND OF DRY AND SATURATED STEAM FROM 185 POUNDS ABSOLUTE PRESSURE TO 1 POUND ABSOLUTE PRESSURE, ASSUMING THAT EQUAL INCREMENTS OF WORK WILL BE PERFORMED IN EQUAL INCREMENTS OF LENGTH OF NOZZLE.
VELOCITY
PRESSURE
AREA OF NOZZLE
VELOCITY OF STEAM, IN FEET PER SECOND.
ABSOLUTE STEAM PRESSURE, IN POUNDS PER SQUARE INCH.
AREA OF NOZZLE, IN SQUARE INCHES.
KINETIC ENERGY OF JET, IN FOOT POUNDS.

It is a general impression that the 1 to 1 velocity ratio must hold in reaction turbines. This is not the case, for, as has been said, the reaction system not only contains impulse principles but also uses side jets, so that the relative blade and jet speed, for the best efficiency, must fall somewhere between .5 and 1.0.

The multi-stage, (Rateau) impulse system was developed to overcome the chief difficulty of the simple impulse element, viz., the efficient utilization of the enormous steam speeds resulting from a single expansion over wide ranges of pressure.

Fig. 9 plots the velocity resulting from the expansion of steam from a pressure of 165 pounds to 1 pound absolute in a nozzle designed for uniform work. Thus a steam speed of over 4000 feet per second is obtained for the full expansion to 28 inches vacuum. This would theoretically require a speed of 7640 revolutions per minute for an impulse wheel 5 feet in diameter—a mechanical impracticability—but by subdividing the expansion into a number of stages the velocities per stage can be reduced to practical limits. This involves the familiar multicellular construction used in the Rateau turbine.

In the subdivided multi-stage (Curtis) impulse system a modification of the foregoing may be secured, viz., blade speeds two or three times lower than the jet speed may be used. This is accomplished by two or more impulse wheels per stage, each absorbing its share of the total velocity delivered by the nozzles.

With a given jet velocity a two-stage impulse wheel would rotate at one-half the speed of a single impulse wheel, a three-stage wheel at one-third, etc.

It has been shown in Appendix I that the energy of a jet of steam of velocity V is $\frac{V^2}{2g}$, and the velocity of the steam with a suitably designed nozzle is dependent on the drop in pressure through such nozzle.

It is customary to diagram by vectors the action of a steam jet through the various stages of a turbine, making certain allowances, established by practical experimentation, for losses due to the physical properties of steam and the construction of the turbine elements.

In Figs. 10 to 16 inclusive such velocity diagrams are illustrated for the four types of turbines, viz., De Laval, Rateau, Curtis, and Parsons, together with diagrams of the blading of each type. The curves in the diagrams illustrate the action of the steam as regards pressure and velocity through the different stages.

Such velocity diagrams comprehend the absolute and relative velocities of the steam jets and blades, the absolute velocities

FIG. 10.

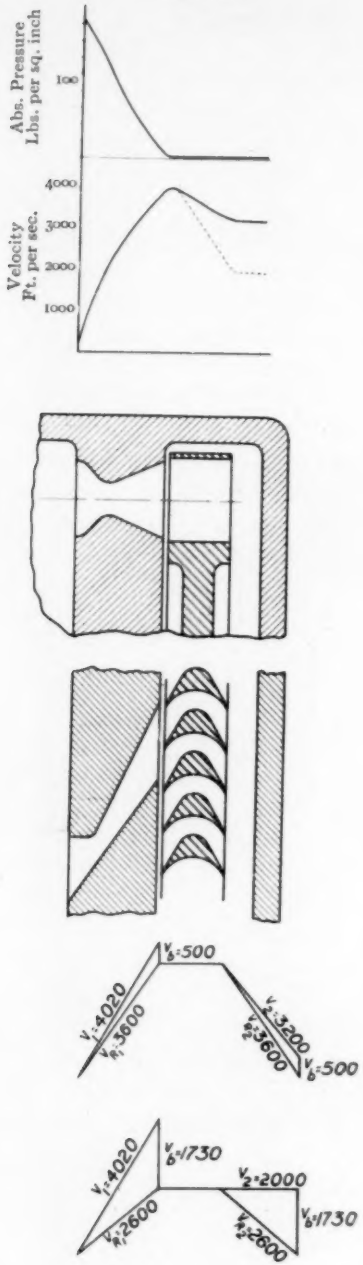
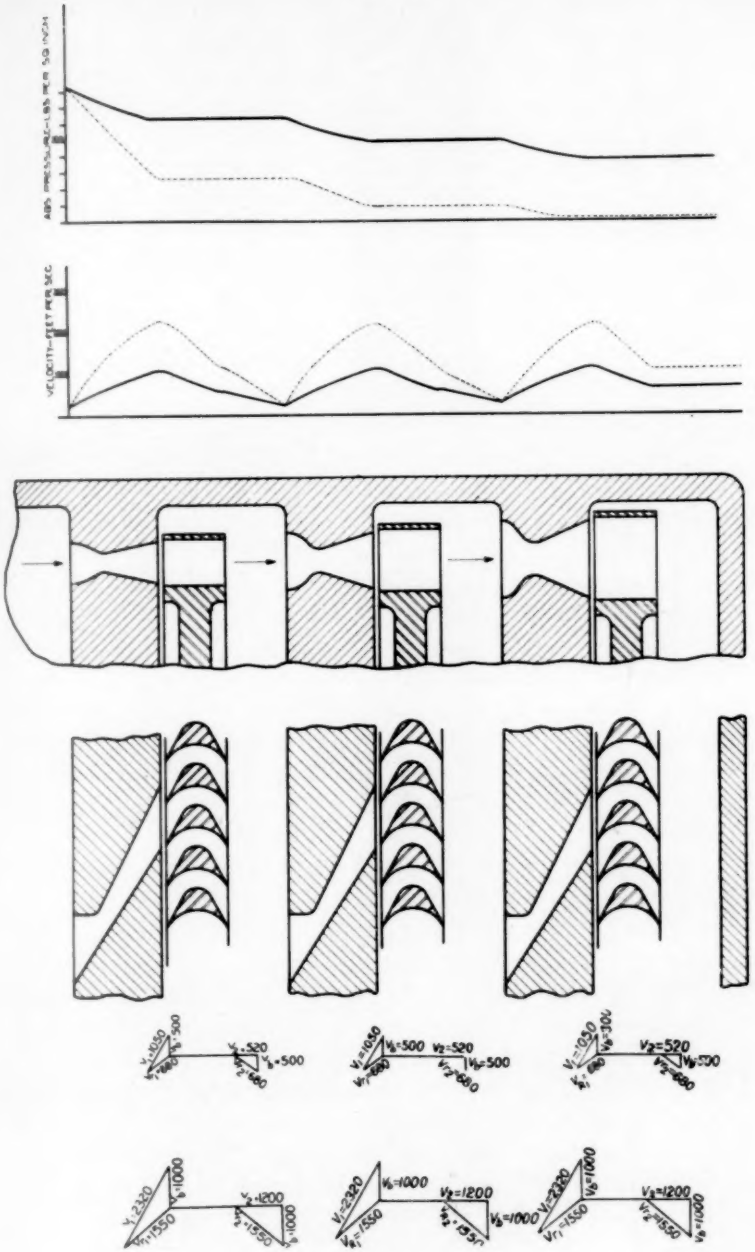

Abs. Pressure
Lbs. per sq. inch
100
Velocity
Ft. per sec.
4000
3000
2000
1000
V_1=4020
V_{θ_1}=3600
V_{θ}=500
V_2=3200
V_{θ_2}=3600
V_{θ}=500
V_1=4020
V_{θ_1}=2600
V_{θ}=1730
V_2=2000
V_{θ_2}=2600
V_{θ}=1730

FIG. 11.


ABS. PRESSURE—LBS. PER SQ. INCH
VELOCITY—FEET PER SEC.
V=1050
Vw=500
Vr=680
V=520
Vw=500
Vr=680
V=1050
Vw=500
V2=520
Vr=680
Vr2=680
V=1050
Vw=500
V2=520
Vw2=500
Vr=680
Vr2=680
V=2320
Vw=1000
Vr=1550
V2=1200
Vw2=1000
Vr2=1550
V=2320
Vw=1000
V2=1200
Vw2=1000
Vr=1550
Vr2=1550
V=2320
Vw=1000
V2=1200
Vw2=1000
Vr=1550
Vr2=1550

being recorded with reference to the earth, and the relative velocities with reference to the blades and steam jets.

In the diagrams Figs. 10 to 16 the turbine rotors of the different types are taken with blade speeds of 500 feet per second and an expansion of the steam from 165 pounds absolute to 1 pound absolute.

In the diagram of the De Laval turbine (Fig. 10) it will be seen that the jet of steam has a residual or leaving velocity after passing the wheel of 3200 feet per second, which results in a failure to abstract the full energy of the jet proportional to the square of such residual velocity. In order that one row of impulse blades such as obtain in this example might extract the maximum energy from the expansion of the steam from 165 pounds to 1 pound absolute, it would be necessary to have a blade speed of 1730 feet per second.

In the Rateau machine (Fig. 11) the residual velocity is 2880 feet per second, representing an amount of energy unabstracted by the turbine proportional to the square of this residual velocity.

If additional stages were added, this residual velocity could be abstracted without change in the blade speed, or the number of stages could be kept the same by increasing the blade speed to 1000 feet per second.

In the Curtis turbine, by subdividing the impulse elements into two, three, or four rows of moving blades per stage the same jet velocity may be used with a blade speed of 500 feet per second, with leaving losses as shown in the diagrams Figs. 12 to 14 inclusive.

It will be noted, however, that in the four-division stage extreme velocities are encountered, as in the De Laval wheel.

These high steam velocities are, as in the Rateau turbine, materially reduced by diminishing the stage division and increasing the number of stages (Fig. 15). This system presents probably the best development of the subdivided multiple-stage impulse turbine; but for a complete machine there are difficulties to contend with in the maintenance of proper steam distribution through the later stages. Considering, however, the first stage, of two subdivisions by itself, the advantage of this type of element is apparent. Comparing, for instance, the first stage expansion with that of a similar expansion arrangement in a

FIG. 12.

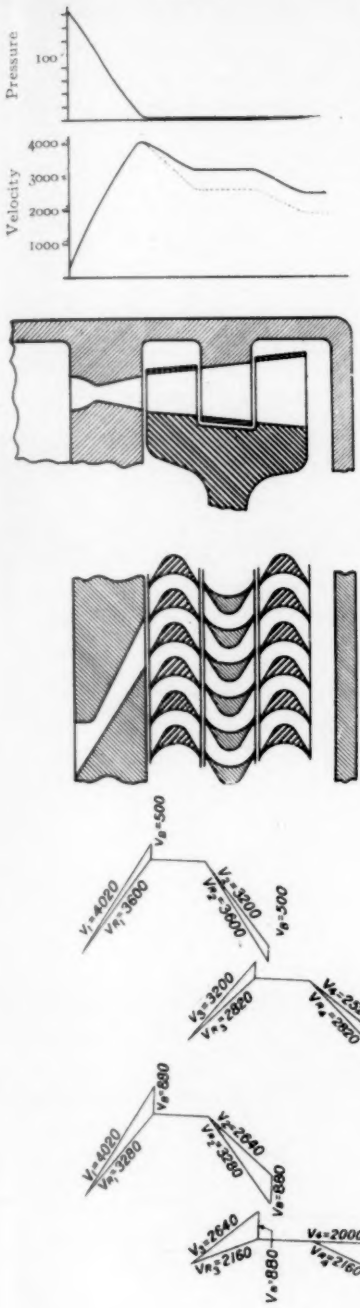

Pressure
100
Velocity
4000
3000
2000
1000
$V_1 = 4020$
$V_{r_1} = 3600$
$V_2 = 3200$
$V_{r_2} = 3000$
$V_3 = 3200$
$V_{r_3} = 2820$
$V_4 = 2520$
$V_{r_4} = 2820$
$V_1 = 4020$
$V_{r_1} = 3280$
$V_2 = 2640$
$V_{r_2} = 3280$
$V_3 = 2640$
$V_{r_3} = 2160$
$V_4 = 2000$
$V_{r_4} = 2160$
$V_0 = 500$
$V_0 = 880$

FIG. 13.

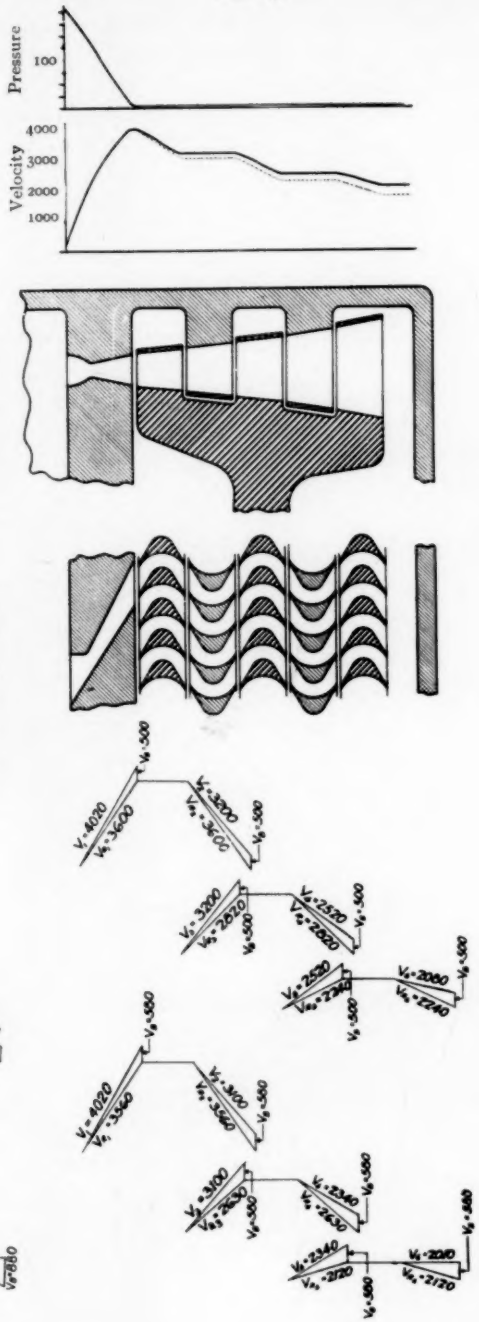
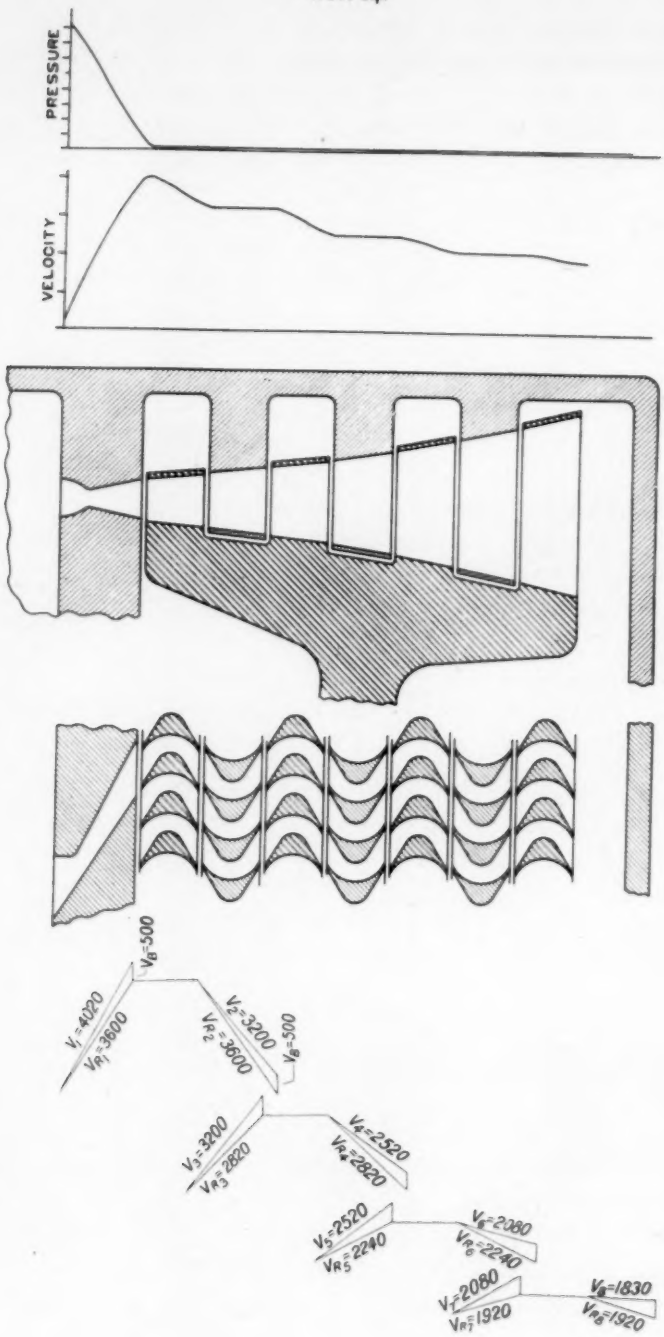
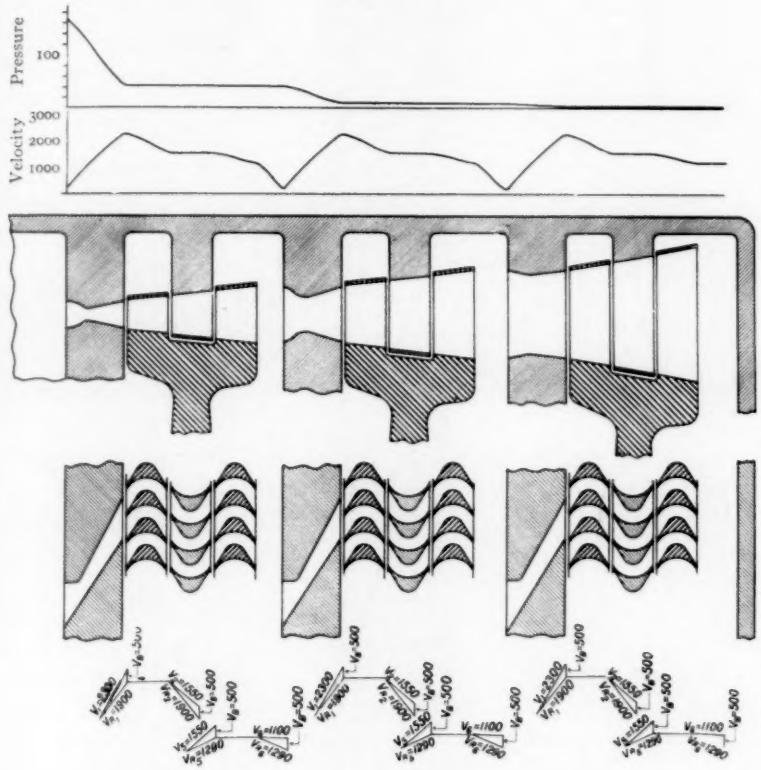

Pressure
100
Velocity
4000
3000
2000
1000
$V_1 = 4020$
$V_{r_1} = 3600$
$V_2 = 3200$
$V_{r_2} = 3600$
$V_3 = 3200$
$V_{r_3} = 2520$
$V_4 = 2520$
$V_{r_4} = 2020$
$V_5 = 2520$
$V_{r_5} = 2240$
$V_6 = 2000$
$V_{r_6} = 2240$
$V_1 = 4020$
$V_{r_1} = 3360$
$V_2 = 3100$
$V_{r_2} = 3360$
$V_3 = 3100$
$V_{r_3} = 2630$
$V_4 = 2340$
$V_{r_4} = 2630$
$V_5 = 2340$
$V_{r_5} = 2120$
$V_6 = 2010$
$V_{r_6} = 2120$
$V_0 = 500$
$V_0 = 880$

FIG. 14.


PRESSURE
VELOCITY
V_1=4020
V_{R_1}=3600
V_B=500
V_2=3200
V_{R_2}=3600
V_B=500
V_3=3200
V_{R_3}=2820
V_4=2520
V_{R_4}=2820
V_5=2520
V_{R_5}=2240
V_6=2080
V_{R_6}=2240
V_7=2080
V_{R_7}=1920
V_8=1830
V_{R_8}=1920

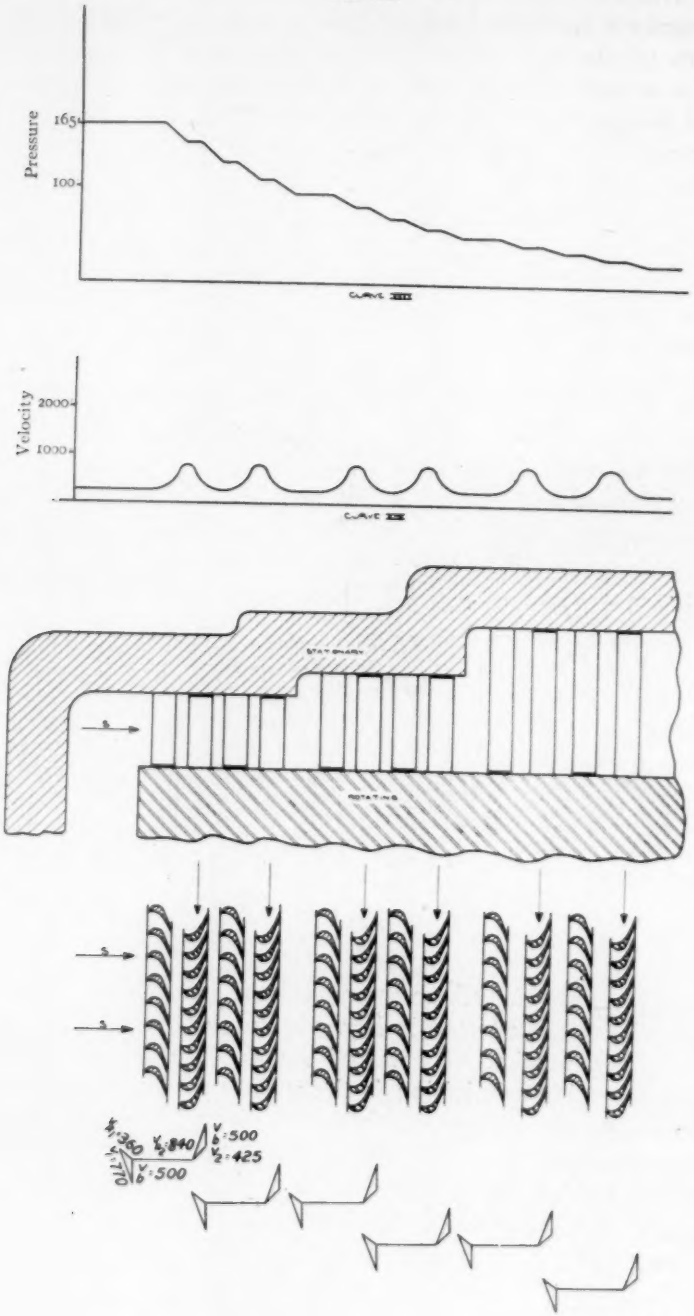
Rateau turbine, it can be shown that four individual Rateau stages are required to do the same work as this single subdivided two-row stage (assuming, of course, the same blade speed, viz., 500 feet a second, and the same pressure drop, 165 to 50 pounds absolute).

FIG. 15.



In the Parsons turbine the process of subdividing the steam expansion (as illustrated in Fig. 16) resolves itself into a relatively large number of rows of blades. An important result secured by this subdivision is the uniformly low steam velocities through the turbine. When velocities of 1000 to 2000 feet per second are encountered throughout the Rateau and Curtis turbines the corresponding velocities in the Parsons machine will vary from 150 to 1000 feet per second.

FIG. 16.



As friction losses are a function of velocity, this relatively low velocity is an important point, and probably to a large degree accounts for the high efficiency of this system.

It is evident from the foregoing that the application of a turbine design to commercial use must embody a knowledge of the properties of steam and its co-relation to the mechanical structure of the machine.

While the pressure-volume diagram is important in the design of piston engines, it has little use, except by comparison, in the determination of the action of steam in the turbine.

The entropy-temperature diagram and the conversion of pressure to velocity under adiabatic expansion, together with the co-relation of heat drops, form the basis of turbine calculations.

The development of the turbine has therefore led to a closer study of the properties of steam, and by experimental work and mathematical deduction the physical properties of both saturated, wet and superheated steam have now been determined with certainty and precision, so that computations based on these show satisfactory concordance.

These principles and the physical laws governing the properties of gases and steam have been shown in Appendix I, from which, with experimental knowledge and calculation, an admirable set of tables on the properties of steam has been compiled by Professor Peabody. From such tables various charts have been plotted, to facilitate calculation, of which Fig. 17 is a good example.

From these tables and charts, for any difference in pressure, superheats, or qualities of steam, the B. T. U. drop, entropy, velocity, quality, specific volume, and energy may be obtained for adiabatic expansion of steam. With the above outline of the elementary principles in turbine design the more recent developments may be discussed as follows:

DE LAVAL TURBINE.

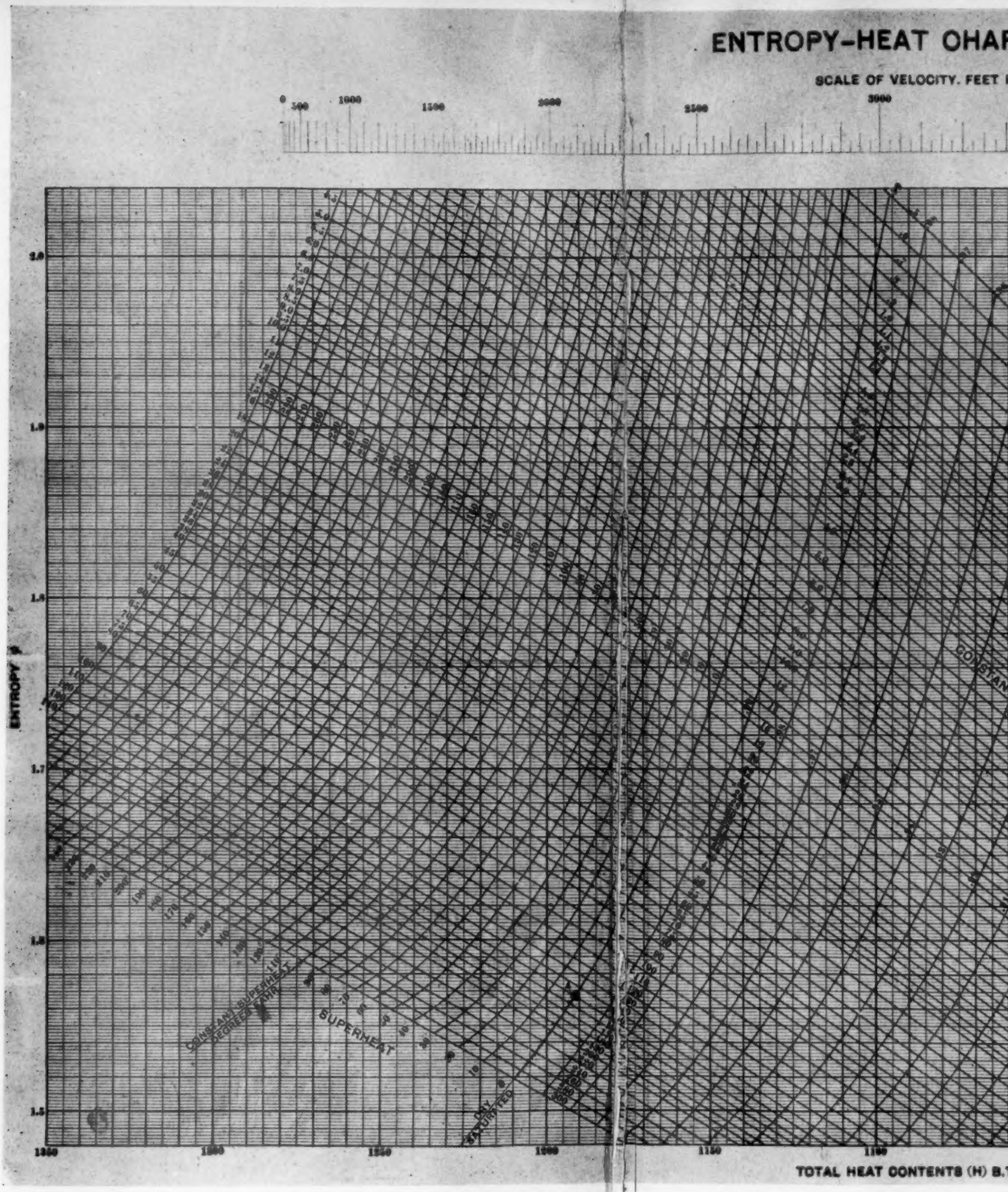
The early trials of the De Laval turbine led to an extended investigation into the proper design of steam nozzles to convert to the best advantage pressure into velocity. To De Laval is due the credit of the design of the expanding nozzle which has been

found necessary in expanding steam in one stage from a relatively high to a relatively low pressure. De Laval's turbine, as has been pointed out, consists of a single row of blades which absorb the velocity obtained by a complete expansion in a single nozzle or a group of nozzles. In order, therefore, to absorb the energy due to the velocity of a jet issuing from the nozzles, it is necessary to have a blade speed somewhere approximating one-half of the velocity of the steam issuing from the nozzle, and where the steam is expanded through a relatively wide range of pressures it becomes impracticable, mechanically, to construct a turbine which with one row of blades will give sufficient blade speed to extract with maximum efficiency the energy from the steam.

On account of the very high speeds, therefore, at which these turbines operate, the development of the De Laval turbine has been closely associated with the construction of disks or wheels of maximum strength. A discussion of the simpler cases of the stresses due to centrifugal forces in disks and drums is shown in Appendix II, from which it may be seen that the speed at which the blades, carried on these disks, may move limits their height, if the stresses in the disk are to be kept within reasonable limits.

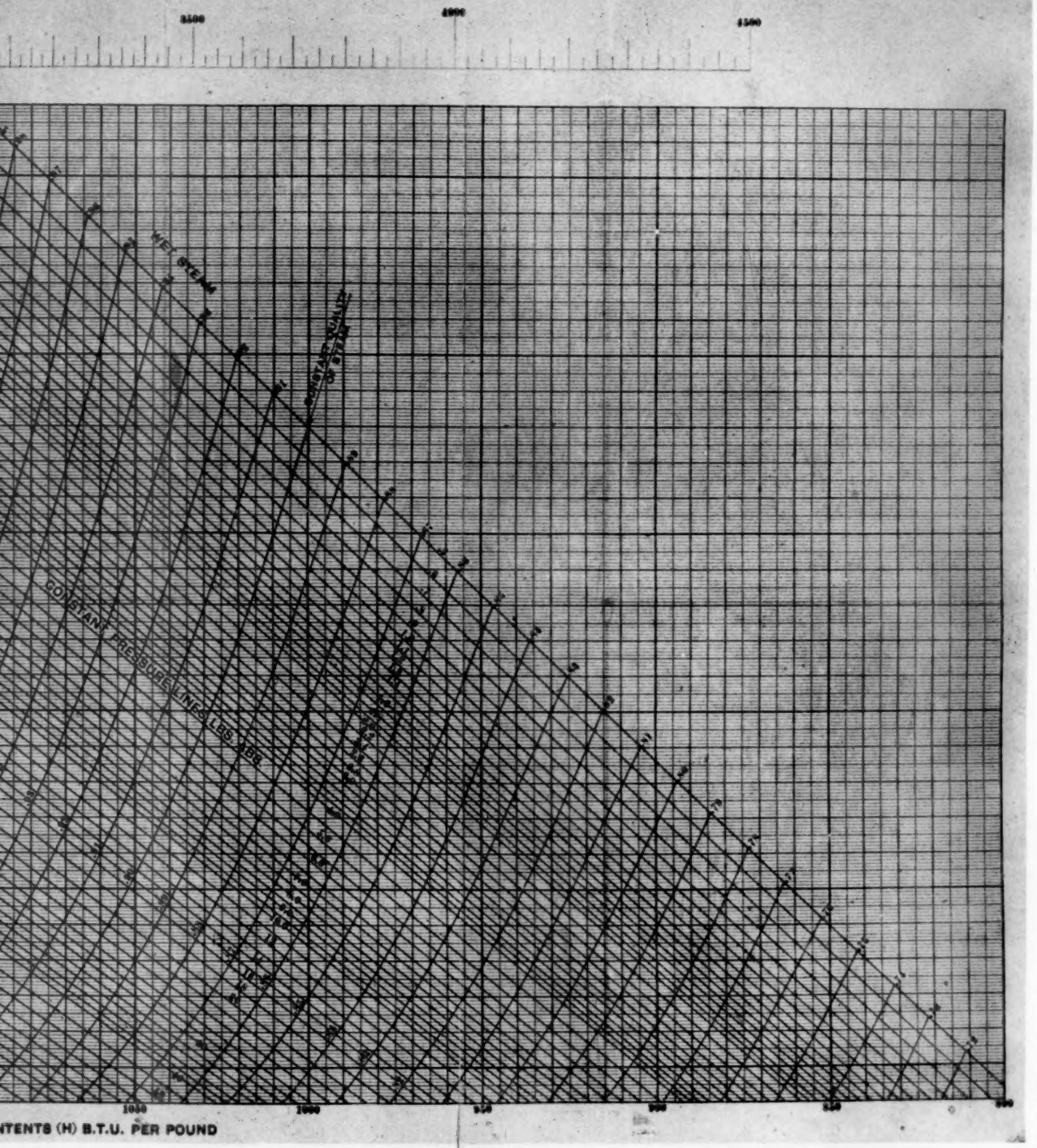
The commendable feature in the De Laval turbine itself is its simplicity. To utilize the high rotative speeds to advantage commercially, however, it is necessary to supplement the turbine with suitable reduction gearing so that the turbine unit, consisting of turbine and gear, must be, for the sake of comparison, taken together, when its advantages and disadvantages are put side by side with the Curtis, Rateau, or Parsons turbine.

On account of the very high speeds at which the De Laval turbine operates, the wheels or disks require very careful designing, and have in recent developments of this machine taken two forms, as illustrated in Figs. 18 and 19. When the design in Fig. 18 is used, there is forced into the bored hub of the wheel, by means of a nut (as shown in the illustration), a thin steel bushing, which bushing is forced on the shaft and pinned in place as shown, before its application to the wheel. This type of wheel has been used in the smaller sizes, but a more recent development has resulted in the design shown in Fig. 19, principally for the


ENTROPY-HEAT CHAR
SCALE OF VELOCITY. FEET
ENTROPY
TOTAL HEAT CONTENTS (H) B.
SUPERHEAT
CONSTAN

T OHART OF STEAM.

LOCITY. FEET PER SECOND.



ITENTS (H) B.T.U. PER POUND

UofM

reason that a disk or a wheel of the disk type, in which there is a hole at the centre, is not more than half as strong as one without a hole.

It will be seen that the form of disk used has a decreasing

FIG. 18.

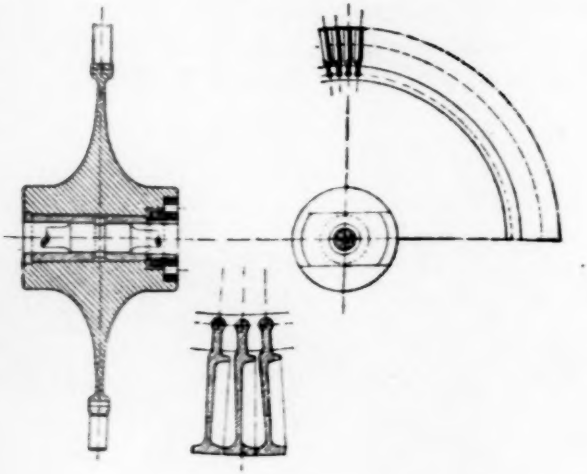
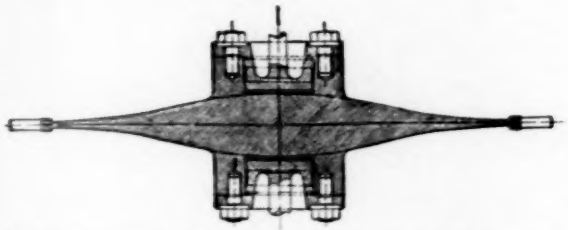


FIG. 19.



De Laval turbine wheel with and without hole in centre, and blading details.

section toward the rim, the proportioning being obtained by designing the disk to have equal unit stresses throughout.

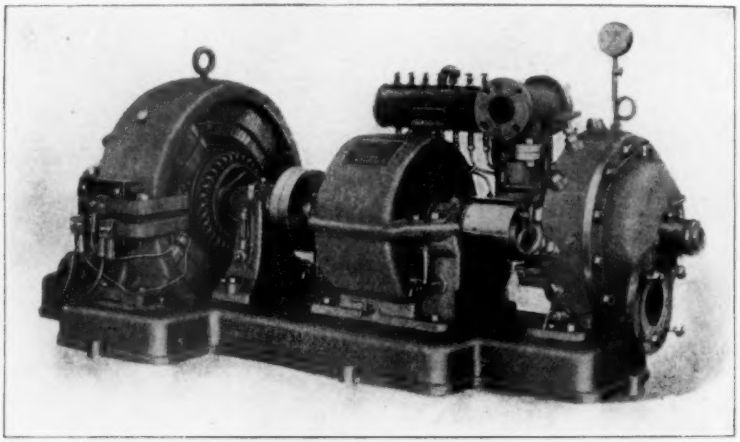
Weakening the wheel at the rim is resorted to as a good method of providing for abnormal stresses that might result in case of the failure of the governor to control the speed, and the wheel is purposely grooved near the rim so that, should the

wheel burst, it will burst at the section where the stresses per unit of area are about 50 per cent. larger than at any other point on the wheel, rather than near the centre, where the damage from failure might be much greater.

Owing to the high stresses encountered in this type of turbine the diameters of the wheels are relatively small, and the materials used exceptionally good.

The following table gives a good idea of the relative proportions of several different De Laval machines:

FIG. 20.



20-horsepower De Laval turbine generator.

Horsepower	5	30	100	300
Revolutions per minute	30,000	20,000	13,000	10,000
Diameter to centre of blades, inches	3.94	8.86	19.68	29.92
Blade speed, feet per second	516	775	1115	1305

Fig. 20 is an illustration of a 100-kilowatt De Laval turbo-generator, from which may be seen the method of arranging the nozzles around the periphery of the turbine wheel. The nozzles are provided with hand valves by which they can be closed when the turbine is running at light loads. In this manner some of the nozzles are cut out, and relatively high efficiency may be obtained at light loads. Nozzles are the only parts of the De Laval turbine which are required to be changed with changing conditions of pressure, quantity of steam, or vacuum.

As the quantity of steam flow is proportional to the differences of pressure on either side of the nozzle, the areas of the cross section of the nozzle at the throat and at the mouth, and therefore its divergence or taper, are determined by the difference of pressure required in each case.

For the same output more steam is required at low pressure than at high pressure, and sometimes the turbine is fitted with two sets of nozzles, one of high back-pressure suitable for non-condensing purposes, and one for low back-pressures suitable for condensing purposes.

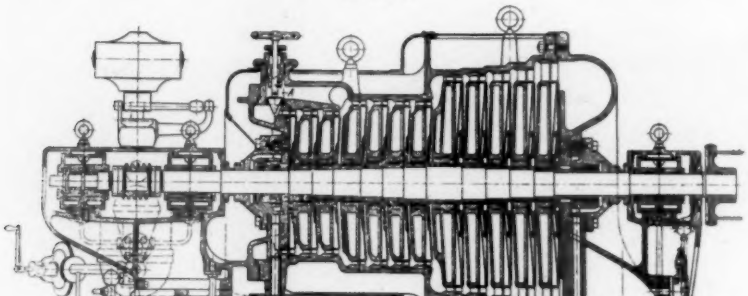
Owing to the high blade speed required in the De Laval turbine, a substantial blade fastening is required. The blades are made of drop forged steel and have bulb shanks fitted to suitable slots in the wheel, as illustrated in Fig. 18. The shrouding of the blades is integral with them. It is exceedingly difficult to construct a high-speed wheel so perfectly balanced that its centre of gravity will coincide with the geometric centre of the shaft with which it rotates. To overcome this difficulty, the De Laval turbine is constructed with a long, slender shaft which, as the speed of the wheel increases, yields somewhat and allows the latter to assume its own position of rotation about its centre of gravity. The difficulties surmounted in balancing these high-speed wheels may be better appreciated by the statement that the weight of one ounce attached at the circumference of the wheel of a 300-horsepower turbine will produce an unbalanced centrifugal force of nearly 2700 pounds.

As has been previously shown, it is necessary, with a De Laval construction, to properly extract the energy of a steam jet due to an expansion from 165 pounds to 1 pound absolute, to have a blade speed of approximately 1730 feet per second, and on account of the mechanical difficulties involved it has been necessary to sacrifice some efficiency to bring the turbine within practical mechanical construction. It will also be apparent that the capacity of the De Laval turbine is proportional to the amount of nozzle area available, and that such nozzle area is limited by the periphery of the disk and the height of the blades. Also, as the height of the blades increases, the load on the disk rim increases, so that a point is reached beyond which the stresses in the disk become impracticable; thus the capacity of the De Laval turbine is limited by the size of the wheel permissible and

by the length of blade that can be used, with due regard to proper stresses in the disk, which limitations have resulted in the construction of the De Laval type of turbine for small powers, and then only by supplementing the turbine with gearing to reduce the high rotative speeds to commercial proportions.

The developments of the De Laval turbine which have borne an important part in the general construction of modern machines have been brought about by the necessity for research (1) in the efficient design of nozzles, (2) the mechanical construction of disks rotating at high speeds, (3) the fastening of impulse blades to properly resist high centrifugal forces, and (4) the construction of double opposed helical gears to reduce

FIG. 21.



Rateau turbine. Built by Engine Works, Oerlikon, 1903.

to commercial proportions the high rotative speeds necessary for a single-disk turbine.

The proper proportioning of the De Laval nozzles is quite important in obtaining the maximum efficiency. Also, it can be shown that the blade angles may be made proper only for one condition of velocity ratios and angles of steam jet and blade.

It is a fact, however, that the De Laval machines of small capacity show good efficiency, compared with other types.

The advantages of this type of machine are: (1) simplicity, requiring only one disk and one row of impulse blades; (2) the absence of packing of any form to prevent the leakage of steam past the turbine elements.

The disadvantages in this type of machine are: (1) necessity

for high blade speed to efficiently extract the energy in the steam; (2) on account of the high rotative speeds, the requirement of high-class materials and the necessity for careful designing to provide for the high stresses in the revolving parts; (3) the limited capacity of the machine, due to the limitation of the blades on account of the centrifugal forces; (4) necessity of reduction gearing in all cases; and (5) medium efficiency.

RATEAU TURBINES.

While the principle of the Rateau turbine is very old, to Professor Rateau is due the credit for its successful commercial development. The general principles of this multicellular type have been shown in the description of Fig. 11, and its construction was principally brought about by the desirability of dispensing with reduction gearing to bring the shaft speed within practical commercial limits.

Fig. 21 illustrates the general construction of this type of turbine as manufactured some few years ago.

This turbine consists essentially of mounting on a through shaft a series of disks which carry at their periphery a row of impulse blades. This series of wheels is mounted in the cylinder casing, which has diaphragms located between the successive disks of the spindle, with suitably-arranged packings between the spindle and the diaphragms. In the diaphragms are carried the nozzles which serve to expand the steam successively, the velocity of which expansions is absorbed by the rotating blades on the several disks.

One of the first machines of this character constructed consisted of 25 stages, and, to mechanically accommodate the length of the machine, was divided into a high- and low-pressure cylinder, as illustrated in Fig. 22.

The large number of disks is employed to keep the peripheral speed of the blades rather low, so that simple construction of the impulse wheels could be resorted to and ordinary commercial materials utilized.

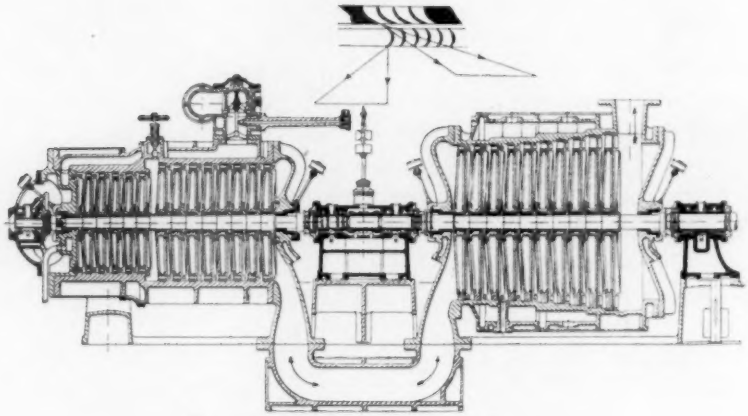
With this construction the energy due to the expansion of steam over wide ranges of pressure may be efficiently extracted.

On account of the blade speed being very much lower than that required in the De Laval turbine, the fastening of the blades to the disks and the construction of the disks themselves

do not require the careful design or construction that obtain in the De Laval machine. It is also practicable, on account of the slower speed of the disk and blades, to very materially increase the disk diameter and also the blade length, resulting in the construction of a machine of very much greater capacity than would be possible with the De Laval turbine.

The nozzles in the Rateau construction are housed in the diaphragms and occupy only such portion of the periphery of the diaphragms as is required for the passage of the proper amount of steam from stage to stage. The increase in blade

FIG. 22.



Rateau turbine, built by Sautter Harle, 1902.

heights and space occupied by the nozzles on the periphery of the diaphragms admirably takes care of the increasing specific volume of steam during the expansion from stage to stage.

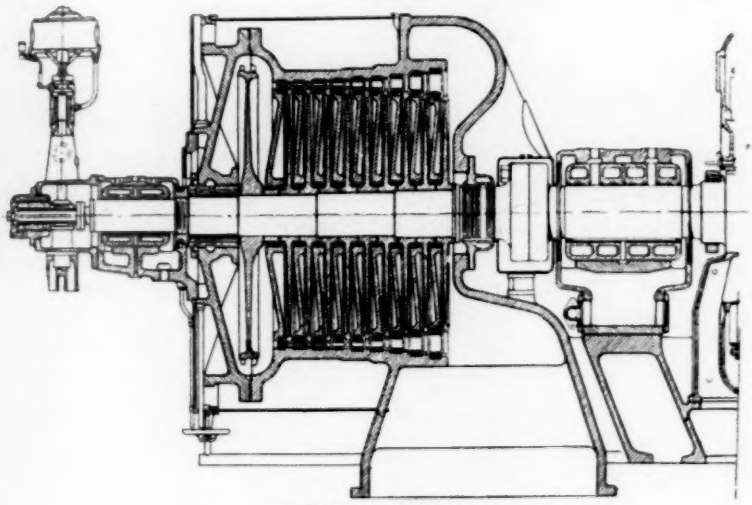
The construction of these turbines is, however, expensive on account of the large number of rotating wheels and their corresponding diaphragms, with the necessity of close clearance or some kind of packing between the diaphragms and turbine spindle to prevent leakage of steam from stage to stage, and the recent developments in the Rateau turbine have led to an increased blade speed, thus materially shortening the machine by reducing the number of stages required for complete expansion.

As in the De Laval turbine, the necessity for proper nozzle and blade design in the Rateau turbine is apparent; in fact, owing to the multiplicity of stages, these two elements of the turbine

require the closest attention to obtain the maximum efficiency; likewise, it is essential to prevent leakage of steam from stage to stage, which problem is not encountered in the De Laval construction. It is also apparent that with the disk construction in the multicellular type it is necessary to add weight to the spindle to secure that rigidity which will prevent undue bending moments on the turbine spindle, thus involving the necessity for packing at larger diameters between the various stages of the machine, with the consequent increase in loss by leakage.

By increasing blade speeds a shortening of the machine may

FIG. 23.



A. E. G. turbine, 1906.

be accomplished, which results in a lighter spindle with less distance between the bearings, and consequently a less bending moment to disturb the proper balance of the spindle while rotating. To further accomplish this shortening in the machine the firms building the Rateau turbine have resorted in the first stages to the Curtis wheel, thus replacing several of the Rateau elements, even with some slight sacrifice in the efficiency. Fig. 23 represents a construction of this kind.

The replacement of several of the Rateau stages by the Curtis element also has the advantage of materially reducing the pressure and temperature which enter the main casing of the ma-

chine, diminishing the probability of undue distortion of the cylinder and spindle.

The advantages of the Rateau turbine as obtained by the multicellular construction are: (1) reduction of speed to commercial limits as regards the application of the turbine to driving electric generators; (2) the reduction in blade speeds, resulting in the construction of disks from ordinary commercial steel and the mounting of the blades on these disks in a simple and effective manner; and (3) the increase in the diameter of the machine to permit of large capacities by accommodating a large number of nozzles around the periphery of the diaphragms, and allowing longer blades to be used without exceeding safe limits in the matter of blade stress in the disk, due to centrifugal force.

The disadvantages in the Rateau turbines are: (1) the necessity for packing along the shaft between the stages; (2) requirements of through shaft construction on which disks with holes are mounted; and (3) the necessity for nozzle control in the various stages for obtaining high economies at light loads, thus increasing the complicacy of the governor and control mechanism, or the sacrifice of economy to avoid such complication.

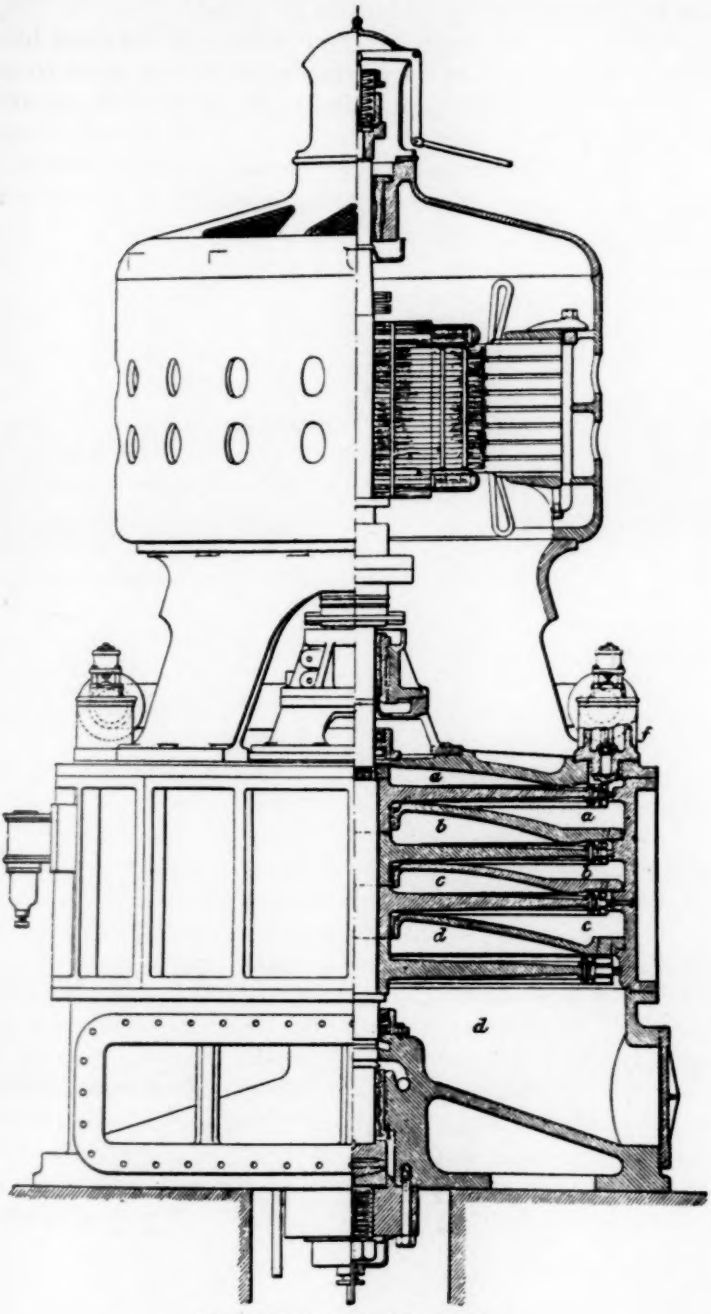
CURTIS TURBINES.

In the recent development of the Curtis turbine the tendency has been to recede from three or four to two moving rows of blades per stage, on account of better efficiency resulting from the latter construction.

Each stage of the Curtis turbine usually contains one wheel carrying two, three or four moving rows of blades, and between the successive stages is interposed a diaphragm similar to the construction followed in the Rateau turbine. The general construction of the machine is shown in Fig. 24. The steam, entering the nozzles of the first stage, is expanded to high velocity, the jet first impinging on the first moving row of blades, through which it passes to the stationary row, whose function it is to redirect the jet to the second row of blades, and so on. There is, therefore, per stage, one more row of moving blades than stationary blades, and each stage, therefore, contains three or more rows.

Like the Rateau turbine, the Curtis machine has partial ad-

FIG. 24.



Vertical Curtis turbine (about 1902)

mission in the high-pressure stages which allows better proportioning of the nozzles and blading; also, since the steam admission only covers a small part of the periphery of the wheel in the high-pressure stages, it is not necessary to continue the stationary row of blades beyond a distance much greater than that occupied by the mouth of the nozzles.

As has been shown previously, the object of the fractional extraction of velocity in the different stages of the Curtis turbine is to increase, for a given blade speed, the exit velocity from the nozzle, and consequently the absorption of a larger amount of energy per stage than obtains in the Rateau machine, blade speeds being equal. Consequently, in the expansion of steam through a given range of pressure, less stages in the Curtis turbine are required than in the Rateau turbine, resulting in a cheaper construction and a shortening of the machine.

The pressure of the steam in each stage is the same in all parts of the chamber, because the drop in pressure occurs almost entirely within the nozzles; but, since the drop in pressure per stage is greater than in the equivalent Rateau turbine, the difference in pressure from stage to stage is proportionately greater. It therefore is essential to prevent the leakage of steam from one stage to another past the diaphragms, which results in the necessity for suitable packing between the diaphragms and the spindle.

As leakage from stage to stage results in a loss in efficiency, the diameter of the shaft is made as small as practicable and the packing as good as may be to prevent these leakage losses.

The efficiency of the turbine depending, as it does, both on the conversion of pressure into velocity through the nozzles and the absorption of such velocity by the blading per stage, it is apparent that the Curtis turbine requires careful designing in the proportioning of nozzles for best efficiency, and proper blade angles and passages in the three, five, or seven rows of blades per stage.

In fact, the lower efficiency found in practice from utilizing more than two moving rows of blades per stage has led, in general, to the abandonment of the three, four, or more moving rows of blades per stage, except in certain marine constructions and in turbines of low power, where mechanical or other considerations predominate over the desire for best efficiency.

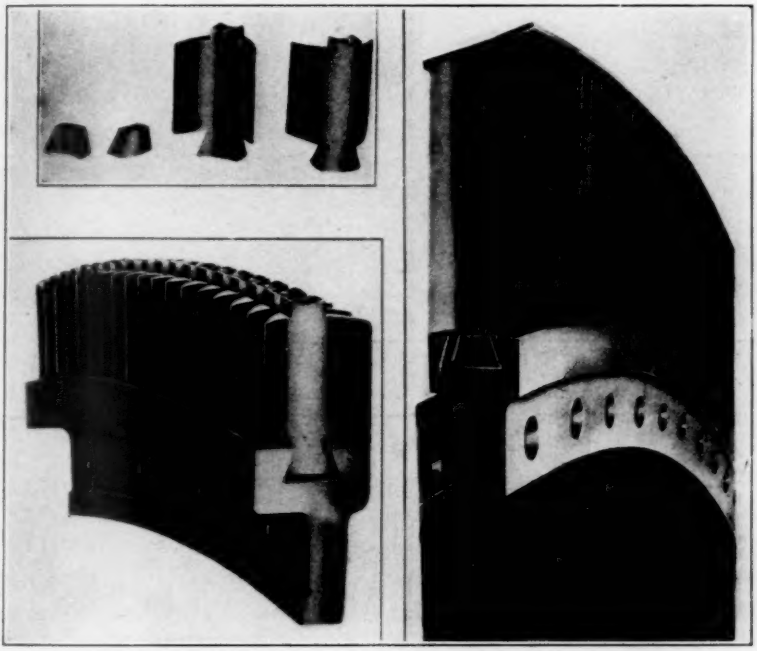
The blade wheels are usually made of forged steel disks

carrying the blades in dovetailed grooves, as shown in Fig. 25. In the larger machines a built-up blade-wheel construction is resorted to, as shown in Fig. 26.

The principal development in this turbine has been carried on by the General Electric Company in America, by the British Thompson-Houston Company in England, and by the Allgemeine Elektricitäts Gesellschaft in Germany.

In the Curtis and Rateau turbines the adoption of higher

FIG. 25.



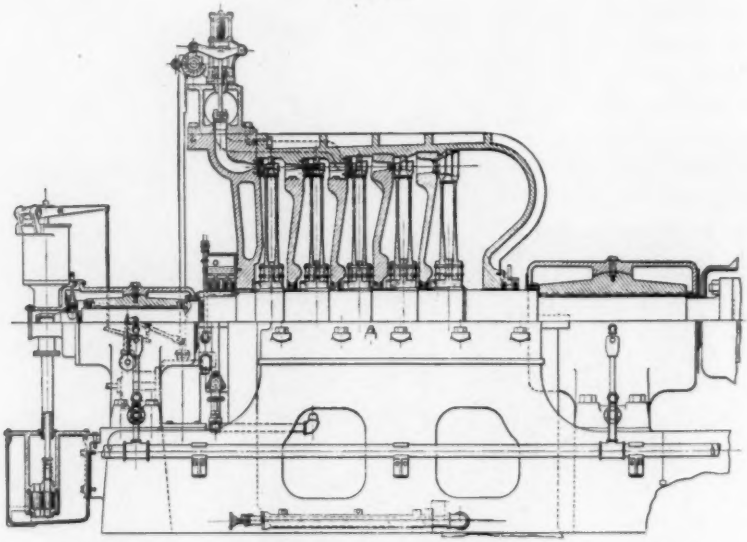
Recent Curtis turbine. Blading structure. (Dovetailed roots.)

blade speeds as the design developed resulted in reducing the number of stages, thus reducing the cost of manufacture and increasing the economy.

The Curtis turbo-generator units of relatively large capacity as built in this country were, until the last few years, constructed with vertical shafts, but recent practice has modified to advantage the construction to the horizontal type of machine, which has generally been followed by the Parsons and Rateau turbines since their commercial introduction.

The advantages of the Curtis turbine are: (1) its adaptability and simplicity to the construction of turbines of small capacity where efficiency may in a measure be sacrificed for simplicity. Thus, for non-condensing service a small Curtis turbine consisting of one stage with triple velocity extraction or three rows of moving blades gives a fairly good economy with reasonable rotative speed, as compared with the De Laval turbine, which latter would, under similar conditions, require a reduction gear; (2) the reduction of pressure and temperature of steam passing

FIG. 26.



Longitudinal section through a 3500-kilowatt horizontal Curtis steam turbine.

a Curtis stage results in less severe conditions for the turbine casing than with a Rateau turbine of equal blade speeds; (3) the reduction in the number of stages required for complete expansion, as compared with the Rateau turbine, results in a shorter machine and consequently a more rigid shaft construction, together with a simplification of the turbine elements.

The disadvantages of the Curtis turbine are: (1) its inability to secure highest efficiency in the larger sizes; (2) due to its cellular construction, the necessity for diaphragms and stage packing at the shaft; (3) the necessity for disks with holes, on account of the through shaft construction, and by the necessity

in the design for two moving rows of blades, additional weight imposed on the rim of the wheel, increasing the stresses in the wheel for a given blade height and blade speed, as compared with the single row of blades of the Rateau turbine; and (4) the necessity for nozzle control in the various stages, with its resulting complications where best efficiency is desirable at less than full loads.

PARSONS TURBINES.

The Parsons type of turbine differs from other forms of turbines principally: (1) by the total admission of steam around the narrow space between the cylinder casing and the rotating drum, as compared with partial admission of steam to nozzles in the impulse turbines previously described; (2) the stationary and revolving blades of the Parsons turbine require an expansion of steam through the blades, resulting in a difference of pressure on either side of each row, while in the impulse turbine there is practically no difference in pressure on either side of the moving rows of blades in any one stage: in other words, the Parsons construction may be said to be made up of a series of stationary and rotating nozzles; (3) the governing control of the Parsons turbine must necessarily be done by throttling of the steam when light loads are required, while in the impulse turbine the governing can, on the first and succeeding stages, be controlled by cutting in-and-out nozzles or groups of nozzles.

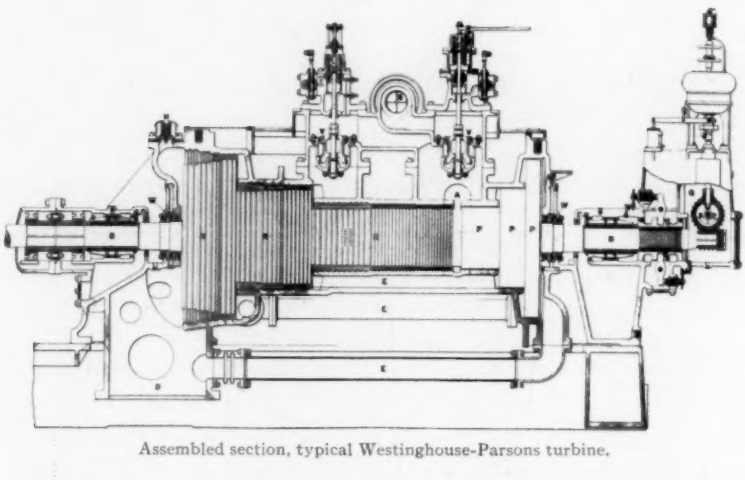
The construction of the older machines built about ten years ago is illustrated in Fig. 27. On account of expansion of steam through the rotating blades it is apparent that an end thrust is set up in the spindle in the direction of the steam flow. One of the earliest developments in this type of turbine was the construction of a balancing piston to compensate this end thrust. It was necessary to so construct this piston that it would allow a relatively high speed of rotation without actually coming in contact with the turbine casing and yet be sufficiently tight to prevent the leakage of large quantities of steam past this piston into the lower stages of the turbine, with a resultant loss in efficiency.

This problem was effectually solved by Mr. Parsons with a multiple stage packing, which provides for small clearances between the successive stages of the packing and allows only such

leakage of steam as can escape by the last stage after its specific volume has materially increased, due to a lower pressure.

On account of the specific volume of steam becoming greater as the expansion goes on in the turbine, requiring, therefore, larger openings through the blades, the lower stages of the Parsons turbine are increased in diameter to provide such opening as is required, and also to increase the blade speed where practicable, thus reducing the number of rows of blades required, since the velocity ratio of blade speed to steam speed is to be kept approximately constant throughout the expansion from stage to stage.[1]

FIG. 27.



Assembled section, typical Westinghouse-Parsons turbine.

The increase in drum diameter of the lower stages of the Parsons turbine requires a balancing piston similar in construction to the high-pressure barrel, and thus in Fig. 27, as there were three different drum diameters, there were provided three balancing pistons as shown, with equilibrium pipes between the end of each stage barrel and its corresponding balancing piston end.

As the spindle blades of the Parsons machine are mounted on a drum, and as there is a difference in pressure on either side

[1] By stages in the Parsons turbine is meant one row of stationary and one row of moving blades.

of each row of blades, it is necessary to have the clearance at the ends of the blades small, to prevent undue leakage over their tips, such leakage vitiating the efficiency which could be obtained if it could be effectually prevented. It will be seen, therefore, that with a given clearance between the tips of the spindle blades and the cylinder or the cylinder blades and the spindle the leakage would, in general, be proportional to the height of the blade, so that if the blade lengths were small the efficiency of the high-pressure end of the turbine would be materially reduced.

Early in the development of the Parsons turbine it appeared, therefore, that with commercial rotative speeds, without the use of gearing, it was necessary that the capacity of the turbine should be relatively large to give good efficiency, especially so as a reduction in blade speed, and consequently steam speed, to maintain a given velocity ratio would result in multiplying the number of rows of blades necessary to properly extract the energy from steam expanding through a given pressure range.

The energy in a steam jet being proportional to the square of its velocity, it can readily be understood that with half a given blade speed four times the number of rows would be required to extract the energy of a given expansion. Consequently, with small powers, it would be necessary to lengthen the machine inordinately to get a proper proportion between the length of the blade and its clearance so that good efficiency could be obtained.

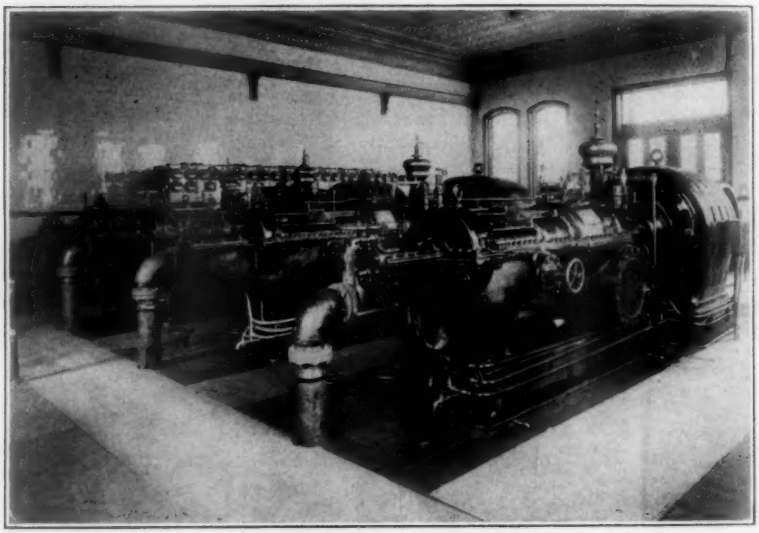
For many years, therefore, the pure Parsons turbine has been confined to designs where relatively high powers are required. As Parsons turbines were designed some ten or twelve years ago, even at powers of 300 or 400 kilowatts, the spindle and casing became quite long as compared with their diameters, and as the steam from the boiler was led directly into the initial stages of the turbine with full peripheral admission, and consequently at full temperatures and pressures, difficulties were encountered in the mechanical construction, due to the long, narrow cylinder and spindle and the relatively wide range of temperatures and pressures in such cylinder.

As the capacity of the turbine increased and the development in the electrical art permitted higher rotative speeds for the turbo-generator, the above condition was very materially

bettered, and with the then moderate steam pressures and temperatures a satisfactory commercial construction of the Parsons turbine was developed.

Through the foresight of Mr. George Westinghouse, The Westinghouse Machine Company became the first licensee under the Parsons patents in 1895, and began the commercial exploitation of this type of machine in America some three years later. Innumerable experiments were carried on by Mr. Westinghouse

FIG. 28.



Power plant of Westinghouse Air Brake Company, Wilmerding, Pa.

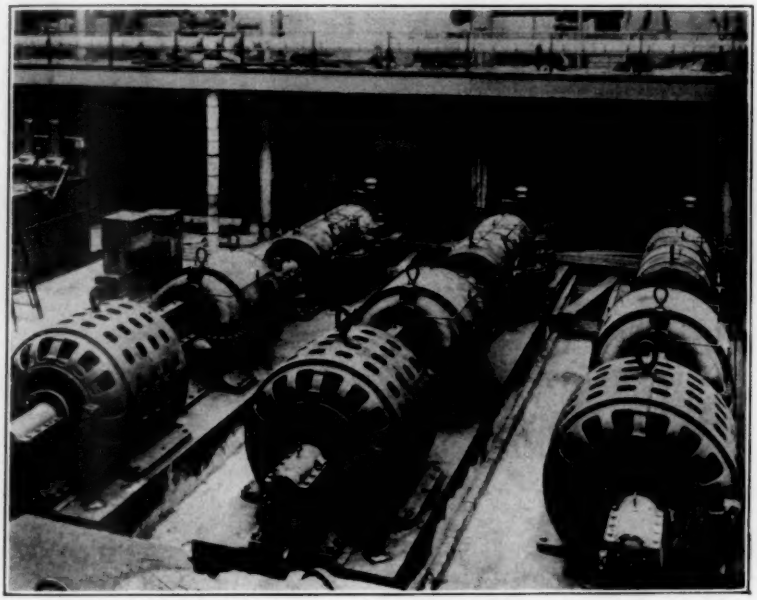
to determine the best blading proportions for turbines, and a general investigation into the turbine art as it was at that time developed.

On account of difficulties encountered in the design of long, slender cylinders, the early Parsons machines were made by dividing the complete expansion into two parts housed in separate cylinders. This overcame the difficulty experienced with the single cylinder machines until the capacity demanded by large turbo-generator units of high rotative speeds allowed the blade speeds to be sufficiently increased to shorten the turbine, and by increasing the diameter of the spindle to stabilize

the mechanical construction so that the complete expansion could be carried out in one casing.

Fig. 28 shows a 400-kilowatt alternating current turbo-generator operating at 3600 revolutions per minute, built by The Westinghouse Machine Company and put into service at the Westinghouse Air Brake Company's plant at Wilmerding, Pa., in the latter part of 1899. Three similar units were built

FIG. 29.



Interborough Rapid Transit Company, New York City.

at the same time, and all four have been in continuous service to date.

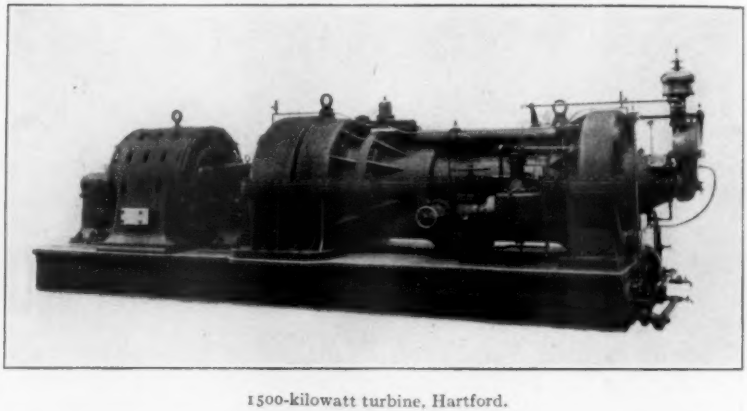
Fig. 29 shows three early 1000-kilowatt turbines of the two-cylinder type built in 1903 and still in service at the Interborough Rapid Transit Company's power plant in New York. These machines operate at 3600 revolutions per minute.

Fig. 30 shows the first large capacity turbine, built in 1900 for the Hartford Electric Light Company. This machine had a capacity of 1500 kilowatts, driving an alternating current generator at 1200 revolutions per minute.

Modifications in the mechanical construction of these turbines constitute the development in the Parsons type.

The advantages in the Parsons type are: (1) ease of construction; (2) the high economy obtained when operating conditions are suitable for proper proportioning of the blading; (3) ability to carry variable loads with good economy; and (4) adaptability to highest efficiency in operating when applied in large sizes.

FIG. 30.



1500-kilowatt turbine, Hartford.

The disadvantages in the Parsons type are: (1) loss in efficiency due to the necessity of blade-tip clearances, especially in machines of small capacity; and (2) difficulty in construction with the use of high-pressure and high superheated steam where long spindles and cylinders are required, due to slow rotative speeds or small capacities.

(To be continued)

Sources of Nitrogen. P. NITSCHE. (*Zeit. Angew. Chem.*, XXV, 2058.)—This is a summary of the existing sources of nitrogenous manures. There is need to enrich the soil with a carbohydrate nutrient so as to afford a cheap source of energy for the nitrogen-fixing bacteria. Waste sulphite-cellulose liquors, neutralized with lime so as to be slightly alkaline, are suggested as well adapted for this purpose; they contain a variety of directly available carbohydrates, as well as lignin substances. Such an application of these liquors would solve the problem of their disposal without polluting the rivers.

CHEMICAL PRODUCTION OF LIGHT.[1]

BY

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For many years the firefly has been an object of admiration and envy to the chemist. The firefly produces light in a very efficient way. The spectrum of the emitted light consists of a narrow band in the yellowish-green portion of the visible spectrum, apparently unaccompanied by any emission in all the ultra-violet or ultra-red portions of the spectrum. As yet, the chemist cannot duplicate this result in spite of the fact that the light of the firefly is due to chemical action. When oxygen is absent, no light is given out. The light is not necessarily connected with the life of the firefly. The dry, powdered, abdominal material of the insects can be kept for as much as two years and will then emit light if moistened and exposed to oxygen. If the chemist could duplicate the abdominal material in the laboratory, he would have a substance which could be made to emit light having the same characteristics as the light emitted by the fireflies.

The chemist cannot do this as yet, and it is not necessary that he should try to, because there are undoubtedly other substances which would be easier to make and which would work equally well. The problem is to find out what these other substances are. There are certainly two ways of attacking a problem like this. One method has been made famous by Edison, and consists in trying every conceivable substance to see which one will be satisfactory. While this method has worked well with Edison in many cases, at any rate up to a certain point, it has not been a striking success in the hands of others, and it is not a method which appeals to a college professor. The Edisonian method is one extreme, and the other extreme is the professorial method. I cannot apply my own name to it, because it was carried to perfection long before I was born. The professorial method, as applied to our problem, consists in studying

[1] Presented at the meeting of the Section of Physics and Chemistry held Thursday, December 12, 1912; based on papers read before the Eighth International Congress of Applied Chemistry in New York, September, 1912.

the way in which light has been produced from primeval times to the present, after which one would naturally discuss the whole theory of the production of light. This method has the advantage of enabling one to write an incredible number of papers without much effort. It is also possible to drop the subject whenever it becomes too difficult; according to Mr. Edison, this is what usually happens.

The professorial method is the one that I am going to consider, though I shall not go back so far as to quote from a paper that I think I once read, on the kind of oil used in the lamps in the hanging gardens of Babylon. At the present day, artificial illumination is caused chiefly by heated solids. In the case of the incandescent lamp, this is obvious; but there might be some question about light from gas or oil.

This point has been discussed by Mendeleeff,[2] from whom I quote:

"Flames are of different degrees of *brilliancy*, according to whether *solid* incandescent particles occur in the combustible gas or vapor, or not. Incandescent gases and vapors emit but little light by themselves, and therefore give a paler flame.[3] If a flame does not contain solid particles, it is transparent and pale, and emits but little light.[4] The flames of burning alcohol, sulphur, and hydrogen are of this kind. A pale flame may be rendered luminous by placing fine particles of solid matter in it. Thus, if a very fine platinum wire be placed in the pale flame of burning alcohol—or, better still, of hydrogen—then the flame emits a bright light. This is still better seen by sifting the powder of an incombustible substance, such as fine sand, into the flame, or by placing a bunch of asbestos threads in it. Every brilliant flame aways contains some kind of solid particles, or at least some very dense vapor. The flame of sodium burning in oxygen

[2] The Principles of Chemistry, I, 176 (1891).

[3] All transparent substances which transmit light with great ease (that is, which absorb but little light) are but little luminous when heated; so also substances, which absorb but few heat rays, transmit few rays of heat when heated.

[4] There is, however, no doubt but that very heavy, dense vapors or gases under pressure (according to the experiments of Frankland) are luminous when heated, because, as they become denser they approach a liquid or solid state. Thus detonating gas is brightly luminous when exploded under pressure.

has a brilliant yellow color, from the presence of particles of solid sodium oxide.[5] The flame of magnesium is brilliant from the fact that in burning it forms solid magnesia, which becomes white hot, and similarly the brilliancy of the Drummond light is due to the heat of the flame raising the solid non-volatile lime to a state of incandescence. The flames of a candle, wood, and similar substances are brilliant, because they contain particles of charcoal or soot. It is not the flame itself which is luminous, but the incandescent soot it contains. These particles of charcoal which occur in flames may easily be observed by introducing a cold object, like a knife, into the flame.[6] The particles of charcoal burn at the outer surface of the flame if the supply of air be sufficient; but, if the supply of air be insufficient for their combustion, the flame smokes, because these unconsumed particles of charcoal are carried off by the current of air."

With incandescent solids, the intensity of the light is a function of the temperature, increasing rapidly as the temperature rises, and being independent of the nature of the solid if this is so arranged that it gives what is known as black body radiation,—in other words, if the conditions are such that no light can be reflected by the incandescent solid. This condition is not fulfilled strictly with ordinary illuminants; but the error is not of any serious importance in most cases. With temperature radiation, as it is called, the ratio of the visible radiations to the invisible radiations increases with rising temperature, and consequently we get the maximum efficiency at the highest temperature. Since the osmium, tantalum, and tungsten lamps have been developed in consequence of a clear understanding of this principle, it seems probable that we are approaching the limit of efficiency which can be reached in this way.

It seems probable now that the greatest progress is to be made by turning to other methods of producing light and by taking the modest firefly as our model. A step has already been made in this direction. The Moore light, for instance, and the

[5] [This statement is undoubtedly wrong.—W. D. B.]

[6] If hydrogen gas be passed through a volatile liquid hydrocarbon—for instance, through benzene (the benzene may be poured directly into a vessel in which hydrogen is generated)—then its vapor burns with the hydrogen and gives a very bright flame, because the resultant particles of carbon (soot) are powerfully ignited. Benzene, or platinum gauze, introduced into a hydrogen flame may be employed for illuminating purposes.

flaming arc are cases where the light is not purely a function of the temperature. By putting suitable salts in a Bunsen flame or an alcohol flame we get an emission of light which varies with the specific substance used and which is not solely a function of the temperature. Addition of sodium salts causes a yellow flame, while we get a red one with strontium salts and a green or blue one with copper salts. This is not a case of cold light in the popular usage of the word; but it belongs under this head theoretically.

The forms of luminescence which are not strictly temperature radiations have been classified by various people under the following heads:

Photoluminescence,
Thermoluminescence,
Pyroluminescence,
Electroluminescence,
Cathodoluminescence,
Anodoluminescence,
Chemiluminescence,
Crystalloluminescence,
Triboluminescence,
Organoluminescence.

When light stimulates a substance to emit light, we call it photoluminescence. If the luminescence lasts an appreciable length of time after the exciting light is cut off, we speak of phosphorescence, whereas we usually speak of fluorescence if the emission of light stops apparently at the same moment that the exciting light is cut off. By thermoluminescence we mean the light that is often emitted by phosphorescent substances when heated gently. Pyroluminescence refers to the light emitted by flames in so far as this is not due to the incandescence of solids. Flame spectra come under this head. Electroluminescence is the term for luminescence produced by the passage of an electric current through a gas. Cathodoluminescence is the luminescence produced by cathode rays when impinging on a solid or liquid, while anodoluminescence is the corresponding luminescence produced by canal rays. Chemiluminescence has been used hitherto solely for those cases where nobody could deny that the light must be due to chemical action. The light emitted during the

oxidation of an alkaline pyrogallol solution is a typical instance of chemiluminescence in the narrow sense of the word. Crystalloluminescence is the word used when light is emitted during crystallization from solution, while triboluminescence is used for the light emitted when crystals are crushed. Organoluminescence is the luminescence produced by bacteria, marine organisms, luminous worms, flying insects, etc.

When one glances over this imposing list of terms, it is difficult not to be impressed by the wealth of knowledge which these terms seem to connote. A closer examination shows that this classification is based solely on the methods of producing light and not at all on the actual way in which light is produced. We should not be very much impressed by a man who classified fires under the headings: sulphur-match fires; safety-match fires; flint-and-steel fires; friction fires; lightning fires; spontaneous-combustion fires; crossed-wire fires; overheated-flue fires, etc. This classification might be valuable to an insurance man, but it would not tell us much about the theory of fire. It would be more rational to classify as oil, gas, coal, and wood fires, for instance, while a more careful study would show that all ordinary fires came under the general heading of rapid oxidations. Similarly I intend to show that the ten different kinds of luminescence are all cases of chemiluminescence, of luminescence due to chemical action.

When a substance emits light for an appreciable time after it has been exposed to an exciting light, the very existence of a time factor shows that we are dealing with some sort of a chemical reaction, using the term in its broadest sense. Consequently, all cases of phosphorescence are due to chemical reaction. The same reasoning applies to the case of thermoluminescence so-called. Since most cases of phosphorescence can be converted into cases of fluorescence by raising the temperature sufficiently, and since some cases of fluorescence have been converted into phosphorescence by adding gelatine, etc., to the solution, it seems reasonable to conclude that the difference between fluorescence and phosphorescence is a difference in relative reaction velocities. I am inclined to lay stress also on another argument. Since there is no known way of converting monochromatic light of one wave-length directly at ordinary temperatures, by reflection or refraction, into light of any other wave-length, it follows that

we must have some chemical action taking place whenever luminescence of any wave-length is produced at ordinary temperatures by the action of light of another wave-length. The only reason for putting in the limitation in regard to ordinary temperatures is to head off the possible case where one would have temperature radiations due to the heating action of the incident light. Personally I am doubtful whether even this case is a real exception. It would not surprise me in the least to find that the so-called temperature radiation of solids was due to the giving off or taking up of electrons or something. My knowledge of the subject is not sufficient to enable me to reach a definite conclusion on this point, and consequently it will be simpler not to try to include this form of luminescence under chemiluminescence for the present.

In regard to pyroluminescence and electroluminescence I cannot do better than to base my argument on a quotation from Smithells:[7]

"When solids and liquids are heated beyond a certain temperature by an external source of heat, they become luminous, and the intensity of the light emitted increases very rapidly as the temperature is further increased. There is no reason to suppose that gases would behave differently except in degree, for, according to the kinetic molecular theory of matter, light should arise from molecular vibrations occasioned by molecular collisions. It is doubtful, however—whatever may be the case in celestial bodies—whether a gas has ever been brought by artifice into what may be called a state of purely thermal glow. The high transparency of gases to light is correlated to a very low emissivity: iodine vapor, which is an exceptional gas in its absorptive power, does indeed glow when heated in a glass tube, even when the walls are considerably below a red heat; but there is reason to believe that this glow is connected with the dissociation and recombination[8] of the atoms in the iodine molecule.

"Attempts to heat colorless gases, such as nitrogen, to the glowing point have given negative results.

"In almost every case a *flame is glowing gas*, and in view of the facts just recited we must add the qualification, so far as terrestrial conditions are concerned, that *the glow is the accom-*

[7] Cf. Thorpe: Dictionary of Applied Chemistry, 2nd Ed. 2, 568 (1912).

[8] See especially Evans: *Astrophys. Jour.* 32, 1 (1910).

paniment of chemical change. It would be possible to refine upon this definition. A 'flame' of pure hydrogen in dustless air is invisible according to Stas, the radiation of short wave-lengths being wholly in the ultra-violet. Again, the glow observed during the decomposition of acetylene in a hot tube may be due wholly to the particles of liberated carbon, and in no degree to anything gaseous. But, speaking generally, the basis of flame is a glowing gas, and the exciting cause chemical action. This description would include ordinary hot flames and also flames of the kind called phosphorescent, which may be quite cold in the ordinary sense of the word."

The flame spectra of sodium chloride, strontium chloride, and cupric chloride cannot be temperature radiations from solids, because the temperature is the same in the three cases and yet the flames differ tremendously. They cannot be due to heated gases, because we have seen that it is probable that heated gases do not glow if no chemical action takes place. Consequently we conclude that pyroluminescence is a case of luminescence due to chemical action. In line with this is the fact that the carbon bisulphide flame is rich in ultra-violet rays in spite of its relatively low temperature. Since electroluminescence cannot be a temperature radiation from a heated gas, it must also be due to chemical reactions accompanying or following the electrical discharge.

In some cases, at any rate, the luminescence due to cathode rays or canal rays is similar to that produced by ultra-violet light or to that of flame spectra. For these cases we must therefore conclude that the cathode rays and canal rays produce light as a result of chemical action. Until there is some definite evidence showing fundamental differences between one case of cathodoluminescence and another we must postulate that all cases of cathodoluminescence or of anodoluminescence are cases of chemiluminescence. Under the circumstances it seems safe to assume that crystalloluminescence and triboluminescence are cases of chemiluminescence; and we know that the organoluminescence, so-called, of the firefly is due to chemical action. We therefore generalize that all forms of luminescence, with the possible exception of temperature radiations, are due to chemical action, using the term in its broadest sense.

The generalization that luminescence is always due to chemi-

cal reaction is not new. Pringsheim[9] made out a very strong case twenty years ago for the view that no gas emits light except as a result of chemical action. Armstrong[10] put forward the view, ten years ago, that luminosity and line spectra are the expression—visible signs—of the changes attending the formation of molecules from their atoms, or, speaking generally, that they are consequences of chemical changes. The difficulty is that the generalization has not been taken seriously by anybody, not even by Pringsheim himself. People speak of the carbon spectrum, the cyanogen spectrum, and the carbon monoxide spectrum, for instance, instead of speaking of the spectrum due to this, that, or the other reaction. There has been very little progress in the twenty years since Pringsheim's paper appeared.[11] This is not very surprising. People studied electromotive forces for a great many years before it became clear to them that they ought to speak of the electromotive force of a reaction[12] instead of the electromotive force of certain substances.

Having decided that luminescence is always due to a chemical reaction, we are confronted with two problems, as to the particular reactions in any given case, and as to what reactions give out light and the conditions under which this takes place. I shall consider these two problems separately.

Wiedemann and Schmidt[13] were unable to determine whether the emission of light was due to the decomposition of any given substance or to the reverse reaction. The trouble seems to have been that they wished to deduce this. Theoretically, one should always try to deduce things; but, practically, it often saves time to guess at the answer and then to test the guess. The South African war showed that a flanking movement might be very successful in cases where a frontal attack was foredoomed to failure.

Wilkinson[14] showed what reactions emitted light when cathode rays acted on certain salts by guessing at the reactions and then duplicating them chemically. Under the influence of

[9] *Wied. Ann.* 45, 429 (1892).
[10] *Proc. Roy. Soc.* 70, 99 (1902).
[11] Cf. however, J. J. Thomson: *Chem. News*, 103, 265 (1911).
[12] Haber: *Zeit. Elektrochemie*, 7, 443 (1901).
[13] *Wied. Ann.* 56, 243 (1895).
[14] *Jour. Phys. Chem.* 13, 691 (1909).

the cathode rays, mercury bromide gives an orange glow, cuprous iodide a violet-red one, sodium chloride a bluish-white one, and potassium idodide a green one. He obtained the same type of light by letting the halogen react with the metal under suitable conditions. With halide salts there are not many reactions possible; but the problem becomes more complex when we come to sulphates. The light may be due, for instance, to the reaction between metal and oxygen, the conversion to sulphate not emitting light. The essential reaction may be conversion of oxide to sulphate, or it may be the reaction between metal and sulphate radical. At present the only way to distinguish between these hypotheses is to test each experimentally. This was done by Wilkinson in three cases, and the results are given in Table I.

TABLE I.

Reaction	Light
$PbSO_4$ and cathode rays	blue
$Pb + O = PbO$	none
$PbO + SO_3 = PbSO_4$	white
$Pb + (NH_4)_2S_2O_8 = PbSO_4 + (NH_4)_2SO_4$	blue
$ZnSO_4$ and cathode rays	bluish-white
$Zn + O = ZnO$	green
$ZnO + SO_3 = ZnSO_4$	green
$Zn + (NH_4)_2S_2O_8 = ZnSO_4 + (NH_4)_2SO_4$	bluish-white
$CdSO_4$ + cathode rays	yellow
$Cd + O = CdO$	yellow
$CdO + SO_3 = CdSO_4$	yellow
$Cd + (HN_4)_2S_2O_8 = CdSO_4 + (NH_4)_2SO_4$	white

From this table it is clear that the cathode rays break up lead sulphate and zinc sulphate into metal and the sulphate radical, and that the reverse reaction emits the light. In the case of lead sulphate this conclusion was confirmed by letting the cathode rays act for a long time, keeping the pump going all the time. The lead salt blackened, and a microchemical analysis showed the blackening to be due to metallic lead. So far as the color test goes, all we can say about cadmium sulphate is that the essential reaction is not that between the metal and the sulphate radical. Of the two other possible reactions we naturally select the one between cadmium oxide and sulphur trioxide, be-

cause it must take place before the oxide can be decomposed by the cathode rays. Wilkinson found that cadmium sulphate turns brown when exposed for a long time to the cathode rays while the pump is kept running. This brown product was identified microchemically as cadmium oxide.

So far everything has been satisfactory; but now we come to a difficulty. Wilkinson [15] found that a bluish light was emitted when sodium burned slowly in chlorine or oxygen, while the yellow flame, usually considered characteristic of sodium, was obtained when the combustion took place rapidly. There are thus two reactions which must be separated so far as possible. Both the bluish and the yellow luminescence are evidently due to the sodium, because they are modified but slightly by the nature of the acid radical, though Wilkinson noticed a trace of green in the flame when sodium burned in iodine. We shall come back to this point later. The best method of attacking the problem of the reactions giving rise to the two spectra is to find out under what conditions these two spectra are obtained.

When canal rays act on sodium chloride we get the yellow luminescence,[16] while cathode rays cause the bluish luminescence. Lenard [17] has shown that fused salts of the alkalies are luminescent, the sodium salts emitting a sky-blue light. This being so, one would expect to get a similar spectrum developed somewhere in the Bunsen flame, and this has actually been observed by Lenard in that portion of the flame separating the reducing zone from the oxidizing zone. Lenard also showed that the yellow flame is electrically neutral, while the bluish flame contains ions of some sort. As far as I can make out, the bluish luminescence is the same as the "continuous spectrum" of Kirchhoff and Bunsen.[18]

Bandrowski [19] has made experiments on the emission of light when sodium chloride is precipitated from aqueous solution by alcohol or by hydrochloric acid. When the precipitation takes place under suitable conditions of concentration and temperature, a bluish-white light is emitted. This is so like the bluish lumines-

[15] *Jour. Phys. Chem.*, 13, 703 (1909).
[16] Arnold: *Wied. Ann.*, 61, 326 (1897).
[17] *Drude's Ann.*, 17, 199 (1905).
[18] Kayser: Handbuch der Spectroscopie, 6, 34 (1912).
[19] *Zeit. phys. Chem.*, 15, 325 (1894).

cence of sodium chloride that one is tempted to look upon the two as identical. Owing to the faintness of the crystalloluminescence, it is very difficult to be sure of this fact; but a confirmation, such as it is, may be found in the fact that Bandrowski obtained a greener light when potassium chloride was substituted for sodium chloride. This change is in the right direction, because Lenard found that fused potassium salts emit a green light and that a green light can be obtained with potassium salts in the Bunsen flame.

This point has been taken up recently in my laboratory by Mr. E. F. Farnau,[20] who has confirmed and extended the experiments of Bandrowski :

"After half an hour's wait in the dark room until the eyes became sufficiently sensitive, 50 cc of saturated solutions of each of the salts, sodium and potassium chloride, bromide, and iodide were shaken with 50 cc of alcohol in a 100 cc graduate, and the glow appearing during precipitation was observed. In similar manner concentrated hydrochloric acid was employed as precipitant of the chlorides of sodium and potassium. The results as tabulated [in Table II] indicate the identity of the luminescence, whether produced by cathode rays, chemical combination, or precipitation."

TABLE II.

Color of Luminescence.

Salt.	Cathode ray	Chemical reaction.	Precipitation.
NaCl	bluish-white	blue	bluish-white
NaBr	bluish-white	blue-white	bluish-white
NaI	greenish-white	white (greenish?)	greenish-white
KCl	bluish-white	blue	bluish-white
KBr	blue	blue	blue
KI	green	greenish-white	green

In some cases there is a difference of opinion as to the actual color produced by the cathode rays. Thus Wiedemann and Schmidt [21] obtained a green light when potassium bromide was exposed to cathode rays. Beilby [22] also reports that potassium bromide gives a green light when exposed to the action of beta

[20] Eighth Internat. Congress Applied Chemistry, 20, 127 (1912).

[21] *Wied. Ann.*, 56, 205 (1895).

[22] *Proc. Roy. Soc.*, 74, 511 (1905).

and gamma rays. Experiments made in my laboratory have led to somewhat different results. We find that cathode rays produce a bluish-white light with potassium chloride,[23] a blue light with potassium bromide, and a green light with potassium iodide. We have color photographs which show the differences very well. Since our results agree with those of Wiedemann and Schmidt for potassium chloride and potassium iodide, and since a trace of potassium iodide in potassium bromide would cause the green color, it seems to me quite probable that the alleged green light from potassium bromide was really due to an impurity of iodide in the salts used by Lenard, by Beilby, and by Wiedemann and Schmidt. The salts used by Beilby were undoubtedly impure, because he obtained a pink luminescence with potassium chloride, a result which nobody has confirmed. The question of impurities is of relatively little importance in comparison with the fact that any given sample emits substantially the same light when exposed to cathode rays, when fused, when precipitated from aqueous solution, when placed in the proper part of the Bunsen flame, and when formed by direct synthesis under suitable conditions.

In the case of the fused salt and in the case of the precipitation of the dissolved salt, only one reaction seems possible. We are dealing with the change from the ion to the undissociated substance. There is, of course, no reason why the cathode rays should not disintegrate sodium chloride into sodium as ion and chlorine as ion. It has been proved that lead sulphate is decomposed into lead and the acid radical, and it is more in line with our usual way of looking at things to postulate SO_4'' as ion. The more serious difficulty comes when we consider the slow combustion of sodium in chlorine or oxygen. In order to bring these results in line with the others, we must assume that the reaction between sodium and chlorine or oxygen takes place in at least two stages, sodium as ion being one intermediate product. This is not really a far-fetched assumption. We make a similar one in regard to reactions of metals or gases in aqueous solution. It is a necessary assumption if we are going to consider the formation and decomposition of sodium chloride as a reversible process.

If the change from sodium as ion to the undissociated com-

[23] This was also noticed by Wiedemann and Schmidt.

pound is the reaction which emits the bluish luminescence, we apparently have the change from electrically neutral sodium vapor to sodium as ion as the reaction causing the yellow light which we ordinarily associate with sodium. This would be a legitimate conclusion if we could be certain that there was only one reaction to be considered. This is not the case. Lenard [24] has shown that there are several sodium spectra, and the experiments of Wood and Galt [25] on the fluorescence of sodium vapor lead to the same conclusions. A good deal of work must be done before we can state specifically the reaction corresponding to each spectrum or spectrum series. On the other hand, there seems to be no danger of there not being enough possible reactions. J. J. Thomson [26] has recently shown that we have at least nine different substances when a current passes through oxygen gas: neutral molecular oxygen, O_2; neutral atomic oxygen, O; atomic oxygen with one positive charge, $O^{\cdot}$; atomic oxygen with two positive charges, $O^{\cdot\cdot}$; atomic oxygen with one negative charge, O'; molecular oxygen with one positive charge $O^{\cdot}_2$; ozone with one positive charge, $O^{\cdot}_3$; polymerized oxygen with one positive charge, $O^{\cdot}_6$; free negative corpuscles.

When sodium burns slowly in chlorine or oxygen, the change from sodium as ion to the undissociated compound is the only reaction taking place with sufficient rapidity to cause the emission of light. When the combustion is more rapid, we get the emission of yellow light which corresponds to the second, as yet unformulated, reaction. The intensity of this light is relatively so high that it ordinarily masks the continuous spectrum,[27] having a maximum in the blue. If hydrochloric acid be passed into a sodium flame, the yellow color disappears and we get the continuous spectrum. A mixture of NaCl and NH_4Cl gives very little yellow to an alcohol flame.

The work of Pringsheim [28] brings out clearly the relation between the flame spectra of sodium salts and the combustion spectra. Pringsheim showed that the illuminating gas in the Bunsen flame reduced the sodium salts, and that the yellow light was due to the oxidation. Out in the oxidizing zone of the

[24] *Drude's Ann.*, 11, 636 (1903).
[25] *Astrophys. Jour.*, 33, 72 (1911).
[26] *Chem. News*, 103, 265 (1911).
[27] Lenard: *Drude's Ann.*, 17, 208 (1905).
[28] *Wied. Ann.*, 45, 428 (1892).

Bunsen flame we have rapid combustion, and consequently we get the yellow light, just as we do when sodium burns rapidly in chlorine or oxygen. At the surface separating the reducing zone and the oxidizing zone we have the lowest rate of oxidation, and consequently we should expect to find, what Lenard actually found, the same luminescence which is obtained when sodium burns slowly in chlorine or oxygen. We are not limited now to the chemical reactions which were known twenty years ago, and we do not have to postulate a reaction between sodium and another chemical element in order to account for the yellow light. The value of Pringsheim's work consists in his conception that the reaction causes the light.

Earlier in this paper I stated that the bluish luminescence is modified but slightly by the nature of the acid radical. This is purely an empirical statement; but it is one which is made as a first approximation by all workers in this field. Thus Wiedemann and Schmidt [29] conclude from their work with cathode rays that "in general the color of the luminescence of salts of the same metal is the same. The acid radical has an effect only on the intensity of the light. That some salts of a given metal luminesce, while others do not, is probably an effect of the acid radical." Lenard [30] found that the light was usually dependent only on the metal and not on the acid.

Of course, the generalization that the luminescence of a salt under various conditions depends only on the nature of the metal can only be true when the light emitted by chlorine, oxygen, etc., is negligible. While this is ordinarily the case, Lenard found specific effects due to the acid in the case of phosphates and borates. "The phosphates and borates belong in a special class. In the case of the salts previously mentioned, the color emitted by the fused salt was determined by the metal alone. With the phosphates and the borates, the acid is not only a factor in determining the color of the emitted light, but it is the predominant factor. Potassium phosphate emits blue light in the reduction zone and green light in the oxidation zone; while white light is obtained in the fusion zone, presumably owing to the clouding. Precisely the same effects are obtained with phosphoric acid alone (I used metaphosphoric acid containing a little sodium). Potassium borate remained transparent and dark for

[29] *Wied. Ann.*, 56, 205 (1895).
[30] *Drude's Ann.*, 17, 203 (1905).

a long while in the flame, but finally began to emit blue light. It was found, however, that by that time practically all the potassium had vaporized from the bead and that both the blue light and the green light could be obtained equally well with pure boric acid. Lithium borate and sodium borate also emitted blue light."

Wiedemann and Schmidt's own experiments with cathode rays show that their generalization is only a first approximation. Thus they obtained a white luminescence with potassium chloride and a bright green one with potassium iodide; a yellow one with lead bromide and a beautiful green one with lead iodide. As has already been stated, we find that cathode rays cause potassium chloride to fluoresce bluish-white, potassium bromide bright blue, and potassium iodide bright green. We have not had time to go into this matter carefully, as yet; but it seems probable that the green color observed with some iodides may be connected with the fact observed by Salet [31] that there is a green color in the oxidizing zone when a mixture of hydriodic acid and hydrogen burns in the air. Salet showed the formation of iodic acid under these circumstances; but if the color is due to a reaction of the iodine, it might be obtained under other conditions. A careful quantitative study of luminescence will doubtless show slight differences due to each acid radical. It is quite possible that the specific effect due to chlorine has been overlooked, because it produces whitish light.

Trautz [32] considers all cases of luminescence during crystallization (crystalloluminescence) as cases of triboluminescence or luminescence produced by crushing crystals. In view of what we have seen of the relation between crystalloluminescence, luminescence due to cathode rays, luminescence due to combustion, etc., it is clear that the hypothesis of Trautz cannot be maintained in its present form. I see no objection to wording the hypothesis in another way. I should prefer to say that, in some cases, triboluminescence is the same as crystalloluminescence. When two crystals are rubbed together, one will become electrified positively and the other negatively. One way for this electrification to take place would be by a dissociation, sodium as ion going to one crystal and chlorine as ion to the other. A recombination, or an oxidation of the sodium, would then cause an emission of light which should be the same in quality as the

[31] *Comptes rendus*, 80, 884 (1875).

[32] *Zeit. Elektrochemie*, 11, 307 (1905); *Zeit. phys. Chem.*, 53, 12 (1908).

light emitted under some other conditions. There is no difficulty about confirming this if we stick to sodium salts, because most triboluminescence is apparently bluish-white. Owing to the relatively faint light emitted as triboluminescence, it is very difficult to decide whether potassium iodide, for instance, gives a green light or the mercury halides an orange light. We hope to get definite evidence on this before long; but, for the present, a definite statement is not possible. In the case of sugar and substances of that type, luminescence in the Bunsen flame could not be the same as triboluminescence; but I should expect the triboluminescence to coincide in quality with the luminescence produced either by cathode or by the canal rays, as the case might be.

Having shown how it is possible, in many cases, to discover what specific reaction is emitting light, we can now take up the second question and can ask what reactions give out light and under what conditions. The answer to this is very simple. All reactions tend to emit light, and all reactions do emit light when the reaction velocity is sufficiently high, though the absolute speeds necessary in any two cases may be very different. This is merely a further extension of conclusions previously reached by others. Trautz [33] pointed out that an extraordinary number of chemical reactions are accompanied by emission of light, and that the intensity of light increases with increasing reaction velocity. It is easy to show that some reactions emit no visible light under certain conditions but do emit light when the conditions are more favorable. Wilkinson [34] found that "bismuth, tin, zinc, and cadmium all give negative results when heated in a current of oxygen. However, when cadmium is heated with a blast lamp until it volatilizes, it combines with oxygen and burns with a deep-yellow flame to the reddish-brown oxide. Zinc, heated in the blast to boiling, burns with a green flame." Cases of this sort could be duplicated indefinitely. A very satisfactory experiment is to mix powdered calcium carbonate with red fire. It is very easy to arrange the proportions so that the red fire burns completely without showing any red.

Bandrowski [35] says: "I first studied the crystallization of

[33] Trautz, *Zeit. phys. Chem.*, 53, 1 (1905); *Zeit. Elektrochemie*, 14, 453 (1908).

[34] *Jour. Phys. Chem.*, 13, 704 (1909).

[35] *Zeit. phys. Chem.*, 15, 324 (1894).

sodium chloride, potassium chloride, potassium bromide, potassium sulphate, and potassium nitrate from aqueous solutions. I caused the crystallization to take place under all sorts of conditions: at different temperatures; by evaporating on the water bath, on the sand bath, or over a free flame; by sudden cooling (passing the supersaturated solution through a spiral tube which was kept very cold). In no case was I able to detect any emission of light.

"I accounted for this negative result by assuming that, under these conditions, the ions combined so slowly and over so large a space that the emission of light was too faint to be detected by the eye, more especially since a very intense light was scarcely to be expected even under the most favorable conditions. It became necessary, therefore, to do the experiments under such conditions that the forcing back of the dissociation would be practically instantaneous. It seemed to me that this could be done by adding a liquid which would be miscible in all proportions with water but which would precipitate these salts. Alcohol and aqueous hydrochloric acid are such liquids.

"The experiment confirmed my assumption, and I was able to obtain light effects which were fairly strong with some of the salts, provided the concentrations of the two liquids were adjusted carefully."

Miss Stevenson [36] found that there was no visible light emitted when quinine sulphate was dehydrated slowly, and that a photographic plate was not fogged by a month's exposure to slowly dehydrating quinine sulphate. Visible light is emitted if the dehydration takes place rapidly. There was a possibility that the wave-length of the light emitted during dehydration might be different when the dehydration was slow from that which was emitted when dehydration was rapid. If that were so, there should be a gradual change in the quality of the light if sulphuric acid, containing varying amounts of water, were added to the hydrated salt. This experiment was tried by Miss Stevenson. "The intensity of the light diminished as sulphuric acid, containing more and more water, was added to separate portions of hydrated quinine sulphate. No change in the color of the light could be detected. Moreover, the experiments of Nichols and Merritt,[37] who found that, with varying wave-length

[36] *Jour. Phys. Chem.*, 15, 854 (1911).
[37] *Phys. Rev.*, 19, 18 (1904).

of exciting light, there was no change in the position of the wave-length of maximum density of fluorescent light, make a shifting of the wave-length of the light given off by quinine sulphate less probable."

These experiments of Miss Stevenson are only qualitative and merely make it probable that the variation with varying speed of dehydration is solely in the intensity of the light. We have other evidence that the composition of the light emitted by any given reaction is practically constant. Pringsheim [38] says that in the case of all the non-luminous (faintly luminous) flames, in which the combustion products are chiefly carbon dioxide and water, the radiation seems to depend only on the chemical reaction. The radiation of all these flames seems to be independent of the temperature and to be the same qualitatively [39] and quantitatively [40] when the same amounts of water and carbon dioxide are formed. Fredenhagen [41] confirms this, for he finds that in the whole field of the water vapor spectrum the ordinary hydrogen flame and the oxyhydrogen flame emit practically the same amounts of energy, when referred to equal quantities of water, in spite of the fact that the temperature of the oxyhydrogen flame is approximately double that of the ordinary hydrogen flame.

In the case of the so-called temperature radiation from solids, the quality of the light changes with rising temperature. On the other hand, the change of the intensity with the temperature is described by a general formula applicable to all wave-lengths. If we omit this case, as before, we seem to be justified in concluding that a fairly definite spectrum corresponds to each definite reaction, and that any marked change in a spectrum indicates the occurrence of another reaction.

It is well known that the phosphorescent sulphides of zinc, calcium, strontium, and barium do not phosphoresce unless they contain traces of copper, bismuth, manganese, etc., and it is also well known that the color of the light emitted by the phosphorescing sulphides seems to be determined by the nature and amount of the salts of copper, bismuth, manganese, etc., Wilkin-

[38] *Wied. Ann.*, 45, 428 (1892).

[39] W. H. Julius, *Arch. néerl.*, 22, 310 (1888).

[40] R. V. Helmholtz, Die Licht und Wärmestrahlung verbrennender Gase, 69 (1890).

[41] *Zeit. Elektrochemie*, 14, 458 (1908).

son[42] found that the sulphates of sodium, lithium, potassium, and zinc increase the phosphorescence of cadmium sulphate when exposed to cathode rays, but apparently without changing the quality of the emitted light to any appreciable extent. I interpret this to mean that these salts act as catalytic agents, accelerating the rate of reaction between cadmium oxide and sulphur trioxide, and thereby causing the emission of more light. In the case of the phosphorescent sulphides, the reaction which emits light must be a reaction of the salts of copper, bismuth, manganese, etc., while the sulphides of zinc, calcium, strontium, or barium act as a medium to permit dissociation, just as water does with salts.

If sodium sulphate plays the part of a catalytic agent when cathode rays act on cadmium sulphate, it follows that a cadmium sulphate, which fluoresces but slightly at ordinary temperatures, should fluoresce more intensely at higher temperatures and should scarcely fluoresce at all at low temperatures. This experiment has been tried in my laboratory by Mr. E. F. Farnau.[43]

"The cathode tube used consisted of two parts, into the upper of which was sealed the disk cathode and ring anode, the lower part holding the salt. A two-cylinder Geryk oil-pump maintained the vacuum. The extremely pure salt was exposed in the tube to the cathode emanation and showed little or no luminescence at ordinary temperature. It was hoped that raising the temperature would produce cathodoluminescence. But here a difficulty arose: either due to slow expulsion of occluded gases in the salt or to adsorbed moisture in the glass, or to increased permeability of the glass to air at the higher temperature, the vacuum dropped off, as indicated by the decrease in the characteristic green fluorescence of the glass in the cold parts of the tube. This naturally precluded any possibility of success of the experiment.

"Since rise in temperature produced such disastrous effects, it was decided that the reverse could be tried. The purified salt was replaced by a well-dried commercial sample, which, under cathodo-excitation, glowed brilliantly at ordinary temperatures. All of the tube save about one-quarter inch of the bottom was wrapped with cotton gauze and jacketed in glass. Liquid air was poured on the gauze until it was saturated. The vacuum

[42] *Jour. Phys. Chem.*, 13, 719 (1909).

[43] Eighth Internat. Congress Applied Chemistry, 20, 133 (1912).

improved considerably, as evidenced by the increased cathodoluminescence both of the salt and the glass of the tube. When the vacuum was at its best, the salt, still at room temperature, was cooled by immersion of the bottom of the tube in liquid air. As the salt cooled, its luminescence decreased, as did that of the glass, until it finally became barely visible. The experiment was repeated a number of times, the salt being brought alternately to room temperature and to that of liquid air; the luminescence increased and diminished correspondingly. Similar results were obtained with potassium bromide, which ordinarily shows a bright blue cathodoluminescence."

One consequence of the theory which I have outlined is perhaps of importance for the production of cold light. If we knew what reactions took place in fluorescent solutions, and if we could cause these reactions to take place rapidly by some other excitation than light, we should have these same solutions fluorescing vigorously in the dark. It is along this line that a revolution in lighting will some day take place.

The general results of this paper are:

1. Photoluminescence, thermoluminescence, pyroluminescence, electroluminescence, cathodoluminescence, anodoluminescence, crystalloluminescence, triboluminescence, and organoluminescence are all cases of chemiluminescence, of luminescence due to and accompanied by chemical action.

2. In some cases of cathodoluminescence it is possible to give the chemical reactions taking place.

3. One should speak of the spectrum of a reaction and not of the spectrum of a substance.

4. Any marked change in a spectrum indicates the occurrence of another reaction.

5. The same bluish light is emitted: when sodium burns slowly in chlorine; when sodium chloride is fused; when sodium chloride is placed in the surface separating the oxidizing and the reducing zones of the Bunsen flame; when hydrochloric acid gas is fed into a sodium flame; when sodium chloride is precipitated from aqueous solution by alcohol or by hydrochloric acid; when sodium crystals are crushed.

6. The light effect due to the change from chlorine as ion to undissociated sodium chloride seems to be negligible for the present. More accurate measurements will undoubtedly show the existence of such a light effect.

7. Cathode rays excite the bluish luminescence in sodium chloride, and canal rays the yellow luminescence.

8. The bluish luminescence in the Bunsen flame is found where the rate of oxidation of reduced sodium salts is lowest, at the surface between the reducing zone and the oxidizing zone. The yellow luminescence is observed in the oxidizing zone, where the rate of oxidation is higher. This is in harmony with Pringsheim's experiments on the radiation of sodium.

9. The simplest assumption in regard to the reaction producing the yellow sodium flame is that it is due to the change from sodium to sodium as ion. This hypothesis is inadequate, because it does not take into account the other sodium spectra observed by Lenard and by Wood.

10. Under the influence of cathode rays potassium iodide emits green light. Part of this light is probably due to the iodine. It seems possible that the chlorine may be the cause of some of the white light observed with many chlorides.

11. While it is probable that the triboluminescence of potassium iodide is the same as the crystalloluminescence and the cathodoluminescence of this salt, the experimental evidence is as yet insufficient.

12. All reactions tend to emit light, and all reactions do emit light if the reaction velocity is sufficiently high.

13. The critical reaction velocity, necessary to the emission of light visible to the eye, may be very different with two different reactions.

14. The intensity of the emitted light increases with increasing reaction velocity.

15. The quality of the emitted light varies but slightly with the reaction velocity.

16. The sulphates of sodium, lithium, potassium, zinc, etc., increase the luminescence of cadmium sulphate when exposed to cathode rays chiefly by increasing the rate at which cadmium oxide and sulphur trioxide combine.

17. In the case of the phosphorescent sulphides of zinc, calcium, strontium, and barium, the reaction which emits light is one involving the so-called impurities—the salts of copper, bismuth, or manganese, for instance.

18. It is theoretically possible to stimulate the reactions causing fluorescence by other means than light.

CORNELL UNIVERSITY.

Diminishing the Loss of Metal in Brass-founding. F. BENSEL. (*Metallurgie,* ix, 523.)—The direct addition of zinc to melted copper in an electrically-heated crucible produced hardly any alloy, as the zinc volatilized and oxidized. Several attempts to substitute for the zinc an equivalent quantity of blende, the copper being in sufficient excess to form cuprous sulphide with the sulphur of the blende, and sodium sulphide being used as a flux, were also unsuccessful; the brass produced never contained more than about 12 per cent. of zinc, and great quantities both of copper and zinc were lost in the slag. Sodium and calcium carbonates used to flux the blende were also failures. Finally the metals were melted together in a closed egg-shaped furnace through the centre of which passed carbon electrodes joined by a rod of resistance carbon. The furnace could be rotated so as to agitate and mix the metals, and had a covered opening through which the alloy could be poured. There was practically no loss of zinc, and the resulting brass was almost exactly of the composition, 70:30, it was calculated for. The cost of melting a ton of brass was about $1.50 for power, in a furnace taking a charge of 50 kilos., and about 55 cents for resistance carbon. The saving in zinc, as compared with the ordinary method of manufacture, may be taken at 60 cents per ton of brass.

Electrical Separation of Tar from Coal Gas. A. H. WHITE, J. W. HACKER, and F. STEERE. (*J. Gas Lighting,* cxix, 825.)—An electric separator for separating the tar from crude coal gas by the action of a silent high-tension electric discharge was constructed of an iron cylinder, 12 inches in diameter and 20 feet long, having a tin can wound with cloth hung in the centre, to act as a positive electrode. The gas was treated at temperatures varying from 75° to 150° F. (24° to 65.5° C.), and it was found that the elimination of the tar was so complete that the gas leaving the separator appeared perfectly colorless and left only a faint brown stain on a piece of filter paper through which 1 cubic foot of gas was filtered. In one test the separator operated continuously for five hours upon gas at 154° to 130° F. (68° to 54.5° C.) generated from 400 pounds of coal, the ordinary condensers separating 12.8 pounds of tar and 12.2 pounds of water, and the electric separator effecting a further removal of 17.7 pounds of tar and 2.8 pounds of water. In some experiments the cloth became coated with tar, whereupon the discharge became disruptive and the separating effect was greatly diminished.

Aluminum Nitride. (*Eng. Pat.* 8349, 1912.)—Aluminum nitride is produced by heating a mixture of alumina and carbon, to which catalytic substances, such as metallic oxides, hydroxides, and carbonates, or metals are added, in a current of nitrogen to which varying proportions of free or nascent hydrogen are added.

A RADIOMETER ATTACHMENT FOR A MONOCHROMATIC ILLUMINATOR.*

BY

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HAVING recently had occasion to design a radiometric attachment for a monochromatic illuminator (*e.g.*, Hilger's), a brief description is given herewith, thinking it might be of use to experimenters who are using light-stimuli.

At the present day visible and ultra-violet radiations are being used by chemists for producing photo-synthesis, by biologists who are investigating, for example, the effect of radiant energy upon lower organisms, by psychologists who are studying the effect of light upon the eye, and by physicists who are measuring the photo-electric effect of different parts of the visible and the ultra-violet spectrum.

In all cases it is desirable to know the energy value (mechanical equivalent) of the different wave-lengths used as stimuli; and it is, of course, usually desirable to reduce the energy of the different spectral regions to the same value. For this purpose it is necessary to use a radiometer which functions independent of the frequency of the stimulus. The most useful radiometer which requires but little care is a thermopile. The bismuth-silver thermopile [1] is much more sensitive than a commercial, iron-constantan thermopile, and it has been found useful in measuring light stimuli.

In the present design the bismuth-silver thermopile previously described is mounted securely in an air-tight metal box, *A*, fitted with a quartz window (Fig. 1). The thermopile is mounted upon an insulated support, *C*. The diameter of the bismuth wire is 0.1 mm., and the silver wire is 0.04 mm., as previously described. This metal case moves in vertical ways, which are attached to the spectrometer slit, *B*, by means of screws. When it is desired to measure the intensity of the emergent radiations the thermopile is lowered in front of the slit, *S* (see Fig. 1, "end view"). When it is desired to have the light pass out into space, or when it is desired to make any adjustments or test the calibration, the thermopile is raised above the slit.

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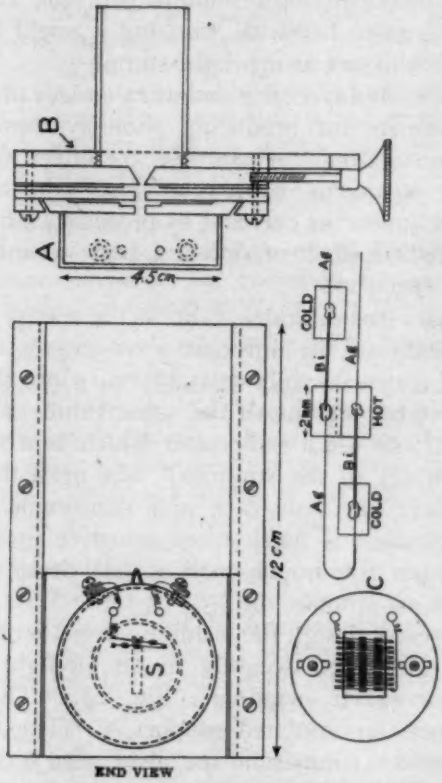
* Communicated by the author.

[1] Coblentz, JOURNAL FRANKLIN INSTITUTE, Dec., 1911. Bull. Bur. of Standards, 1912.

Owing to the extreme sensitivity of these thermopiles it is necessary to have the surroundings at a uniform temperature. For this reason the present design was evolved, hoping thereby to minimize the temperature changes which are encountered in moving the thermopile a great distance from the spectrometer slit. The thermopile is attached to a Thomson galvanometer.

FIG. 1.



In case the thermopile carriage is attached to the ordinary spectrometer slit as shown at *B*, the sloping parts of the jaws should be painted with lampblack. It is desirable to have the (blackened) flat side of the knife-edge face the spectrum, so that the spectrum may be cut off sharp, without passing into the V-shaped trough which is a source of stray light.[2]

WASHINGTON, December 27, 1912.

[2] Since writing this, Adam Hilger, Ltd., has undertaken the construction of this attachment to go with his monochromatic illuminators.

RESISTIVITY OF A FEW METALS THROUGH A WIDE RANGE OF TEMPERATURE.*

BY

EDWIN F. NORTHRUP, Ph.D., and V. A. SUYDAM, B.S.

Members of the Institute.

THE following is a preliminary note and a partial report upon an investigation now in progress and which was begun by Edwin F. Northrup, January 11, 1911, and continued in co-operation with V. A. Suydam since January 1, 1912: The object of this investigation is twofold. First, to perfect a method whereby the resistivities of metals and alloys may be measured with ease, precision, and rapidity through a range of temperature between that of liquid air and a point a little below the boiling point of the substance in question; the same method to be applicable to molten salts. Second, to use this method for obtaining data on metals, alloys and molten salts, which boil under 1500° C., for plotting sets of curves relating the resistivity and temperature over a range of temperature of from 20° C. to near the boiling point of the substance in question.

The method for obtaining data on the metals is sufficiently perfected to permit of ready application (though improvements are being continually made), and the resistivity curves for half a dozen pure metals have been obtained with sufficient precision to make the authors feel justified in reporting upon them at this time.

The resistivity of any substance in the solid state depends upon its nature, the temperature, its purity, and, more than is generally supposed, upon its physical state. This last, in turn, depends upon its past history. If the substance assumes a liquid state, on the other hand, its past physical history is undoubtedly without influence upon its resistivity. Metals in the liquid state and at normal pressures may be expected to always assume the same resistivity when brought back to the same temperature, provided the chemical constitution remains fixed. If they do not return to the same resistivity, at the same temperature, when different samples of what is presumably the same substance are compared in their liquid states, then it may be assumed that

* Communicated by the authors.

the samples differ chemically. The perfection of a method which will measure the resistivities of molten metals at elevated temperatures with a precision comparable to that obtained in the measurement of mercury at ordinary temperatures ought to permit of a delicate discrimination respecting the chemical purity of the samples investigated.

Mercury can be obtained in its liquid state of great purity. It has a high resistivity, and this resistivity is a function only of the temperature, the past history of the liquid metal being entirely without influence. It is therefore, of all substances, the one which is apparently best suited to serve as a standard of resistivity. In our investigation all of our resistivities are referred to the volume resistivity of mercury. We have adopted the values of Kreichgauer and Jaeger, which are—expressed in microhms per centimeter-cube—94.073 at 0° C., 95.782 at 20° C. and 103.56 at 100° C.

Since the difficulties in the way of measuring the resistivities of most of the metals in the molten state have proven to be very great our efforts up to the present time have been concentrated chiefly upon perfecting our methods, and we have only attempted to make our measurements in a manner in which errors of the second order are neglected. Thus the cubical expansion (which is very small) of the container has been neglected. The samples selected have been such as could be obtained from reputable manufacturers, and no attempts have been made thus far to further purify the samples and to chemically analyze those which have been used. Up to the present time we have been satisfied with the attainment of a precision in which the errors in the resistivities of the metals in the liquid state should not exceed 0.25 of 1 per cent., and, for reasons which will appear later, a precision for the resistivities in the solid state in which the errors should not exceed 1 per cent. The precision of the rate of change of resistivities between any two temperatures, for which the material is either a solid or a liquid, is far better than the above. For these relative values the errors in our measurements probably do not exceed 0.04 of 1 per cent., and we believe that in many cases these errors are considerably less. It is our expectation that we shall be able eventually to compare the resistivities of all metals in the molten state, which melt under 1400° C., with an order of accuracy not far different from that

obtained for a metal of large temperature coefficient at room temperature. The method by which the measurements were made has been planned with this precision in view. It is a new one in very many respects, and is being continually perfected with the progress of the work. For this reason we think it would be premature to describe the method at this time. We shall, therefore, defer any detailed description of the method to a later report when it is hoped that further progress shall have brought it more nearly to perfection. We may state in general, however, that the metal to be tested is placed, while molten, in a highly refractory container which does not react chemically with the metal to be tested at the highest temperature attained. Thus far no serious difficulty has been encountered in carrying the temperature, in the case of a metal like copper, to 1430° C. The upper limit possible is still to be ascertained. The measurements are made by a modified application of the Kelvin-double-bridge principle. One of the modifications permits the resistivities for a centimeter-cube to be read directly upon the bridge without calculation. An important feature of the method is that the current and potential terminals always consist of the same material as the substance being measured. The points where the potential terminals join the current terminals are at the same temperature as the section of the conductor being measured. This arrangement insures against chemical contamination. The resistivities are all referred to mercury at 20° C. and are expressed in microhms per centimeter-cube. The temperatures of the metals reported upon were measured, for temperatures above 200° C., by means of a carefully calibrated Pt vs Pt + 10 per cent. Rh thermocouple, and below this temperature with a mercury thermometer.

The data here reported upon refer to the following metals. The chemical analyses are those given by the makers upon the labels on the bottles:

I. *Mercury.*—The mercury used as a standard and for obtaining curve I was redistilled by Dr. G. A. Hulett and was pronounced by him to be very pure.

II. *Lead.*—The sample measured was obtained in the form of thin sheet from the Arthur H. Thomas Company. It was called "test lead" free from sliver.

III. *Cadmium.*—This metal was obtained in the form of

sticks from the Arthur H. Thomas Company. The analysis and purity are not known to the writers.

IV. *Zinc.*—This metal was "Merck's reagent zinc" in drops free from arsenic, sulphur, phosphorus, iron and matter oxidizable by potassium permanganate.

V. *Tin.*—This metal was "Baker's analyzed," purchased in sticks. The analysis given on the label was:

Arsenic, trace.	Zinc, none.
Lead, 0.001 per cent.	Copper, none.
Iron, 0.002 per cent.	

VI. *Bismuth.*—This metal was "Baker's analyzed" in lumps. The analysis given on the label was:

Lead, 0.003 per cent.	Iron, none.
Copper, none.	Arsenic, none.

VII. *Antimony.*—This metal was " Baker's analyzed." The analysis on the label was:

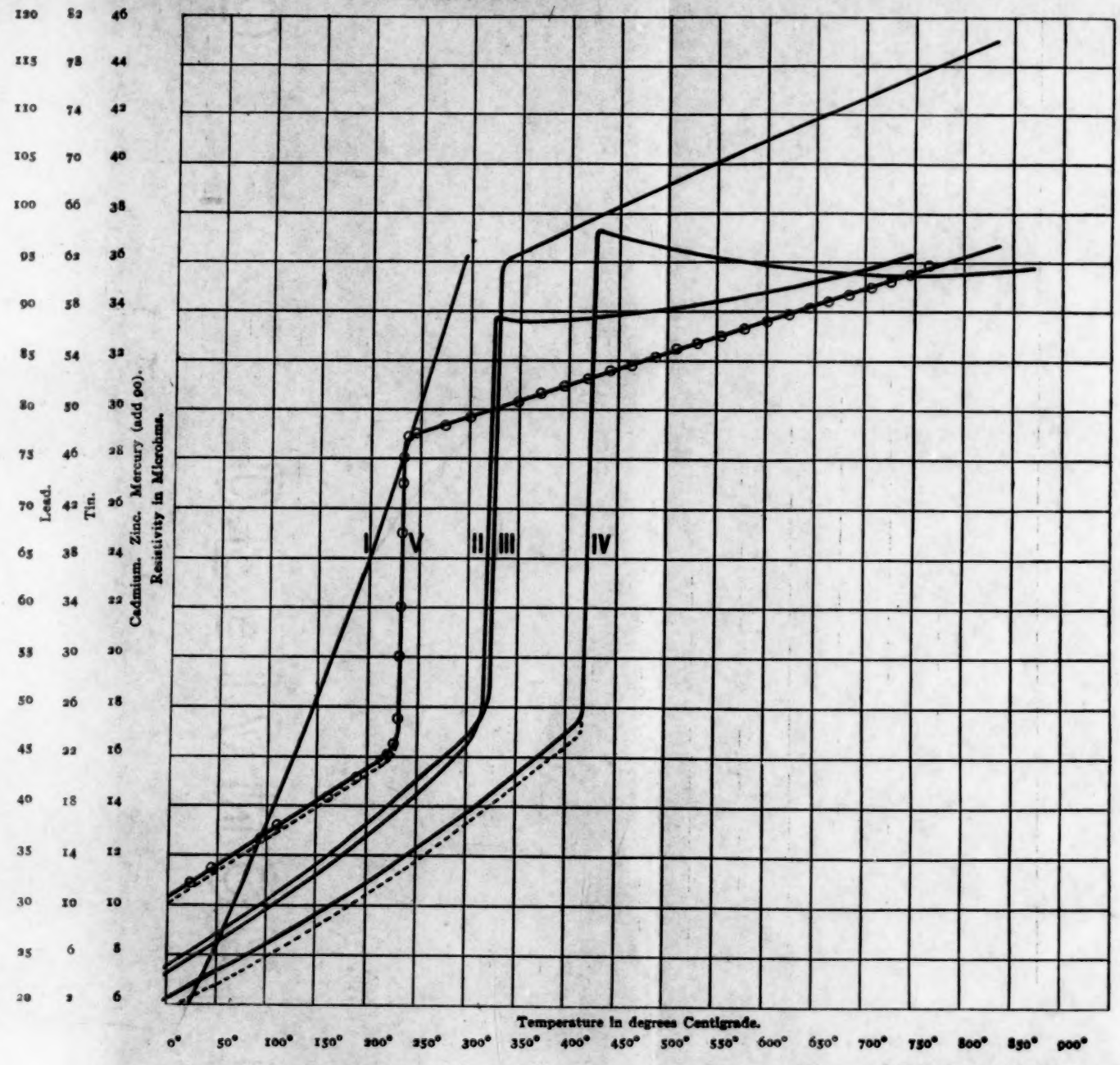
Iron, 0.015 per cent.	Tin, none.
Copper, none.	Zinc, none.
Arsenic, trace.	Lead, 0.001 per cent.

The curves given here are not originals, but much reduced copies of the originals which are drawn upon cross-section paper 20 inches wide with the inch divisions divided into tenths. In these copies the observed points are given only in the case of the curve for tin. They are, of course, given upon the original curves for all the metals, are equally numerous and lie equally close upon the curves as in the case shown for tin.

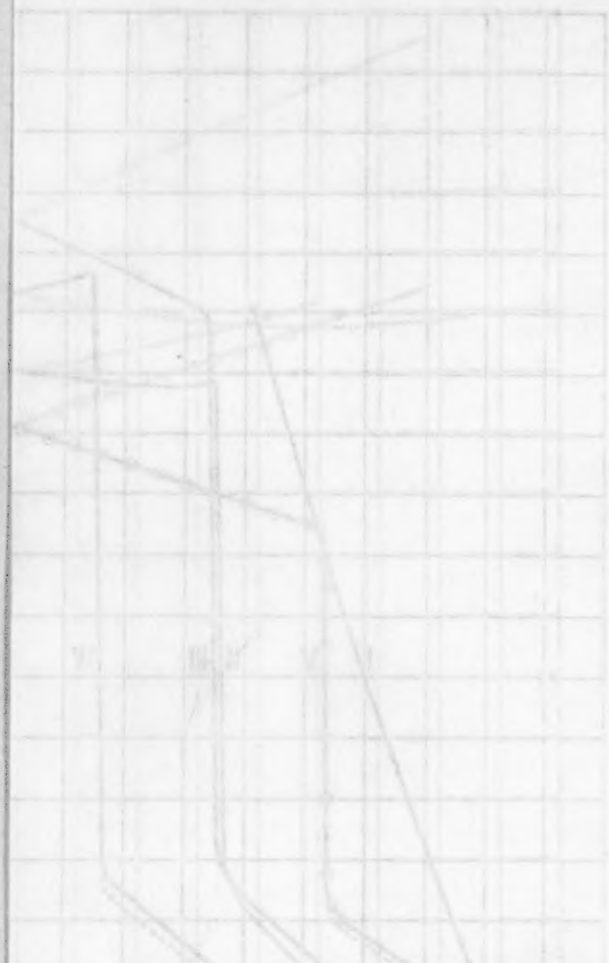
These curves, taken up in order, may be commented upon as follows: Curve I (Fig. 1) is for redistilled mercury. To obtain the resistivity in microhms add 90 to the numbers in the third column from the left. The boiling point of mercury at 760 mm. pressure is given as 356.7° C. Our measurement of resistivity is only carried to 295° C., or 61° C. under the boiling point. The reason for not going higher in temperature is the same one which has limited, thus far, the upper temperature of all our measurements. It was found in this and in the case of the other metals reported upon, that, at the upper temperature at which the measurement stops a bubble of vapor forms in the

FIG. I.

I. Mercury, April 10–13, 1912.
II. Cadmium, April 20–26, 1912.
III. Lead, May 17–18, 1912.
IV. Zinc, Nov. 30–Dec. 4, 1912.
V. Tin, Dec. 11, 1912.



Observers :—E. P. Northrup and V. A. Suydam.



liquid column. The bubble rapidly expands if the temperature is further raised. A first indication of this phenomenon is a very sudden rise in the indicated resistivity being measured, and then, unless the temperature is very promptly lowered (and not always then), the indicated resistivity rises beyond the limit of the bridge and the circuit opens. The first suggestion is that the bubble so formed is some kind of gas. This hypothesis, however, seems to be excluded by the fact that when the temperature is lowered some 20° to 50° C. below the point where the sudden change in the indicated resistivity begins to take place the circuit is restored and the resistivity returns exactly to the same value at any given temperature. If the bubble which forms is due to the vaporization of a trace of impurity originally in the metal, then the return of the circuit and the original resistivity is readily explicable upon the assumption that the vaporized substance recondenses. The explanation is not tenable that the vapor is given off by the container itself or from its walls, for we found no such phenomenon to occur when the container was filled with molten copper at a temperature of 1430° C. Furthermore, there is no fixed temperature at which this formation of vapor occurs, appearing, for example, in the case of the sample of mercury at 295° C. and in the case of the sample of antimony at 915° C. The curve for the resistivity of mercury is regular and very slightly convex toward the temperature axis.

The resistivity increases from 95.78 at 20° C. to 105.5 at 120° C., or an increase of 10.14 per cent. in 100° C.

Curve II (Fig. 1) is for cadmium.

The boiling point of the metal is given as 778° C. The formation of a vapor bubble did not occur until the temperature was raised to 748° C., hence the resistivity of this metal is traced to within 30° C. of its boiling point.

The container is filled with the metal while molten, hence when the container cools down to a point where the metal solidifies a contraction or reduction in cross-section of the metal occurs which is not shared by the container. The resistivity measured is high in the solid state in the ratio of the cross-section of the metal in its liquid state to its cross-section in its solid state. As it is an easy matter to accurately determine the resistivity of the solid metal outside of the container, the method gives a means of deducing the shrinkage of a metal in passing

from the liquid to the solid state. Let a curve be drawn parallel to the portion of the curve drawn from the observed readings which gives the resistivity of the metal in its solid state. If this curve is drawn through points which are assumed to give the true values of the resistivity of the metal in the solid state, then the ratio of the resistivity of the metal just after fusion to its resistivity just before fusion may be obtained by comparing the resistivity just after fusion is complete with the assumed true resistivity just before fusion begins. As no reliable data for the resistivity of cast cadmium were available, the ratio of the resistivity after fusion (33.77 microhms) to the resistivity before fusion (17.1 microhms, estimated) is taken from the curve as drawn. It is estimated at 1.97.

Curve III (Fig. 1) is for lead.

The curve for the solid state is slightly convex toward the temperature axis, and for the liquid state a straight line.

In this case no dotted line is drawn to represent the true resistivity of the metal in the solid state measured out of the container because the data have not been obtained by us, and no published values for lead which had been slowly cooled have been found. The resistivity just after fusion is 94.7 microhms. The resistivity just before fusion is not sharply defined because the change in resistivity in passing from a solid to a liquid is not abrupt but somewhat gradual. If we take 49.2 microhms as the highest value for the solid state, the ratio of the resistivity for lead just after fusion to the resistivity just before fusion is 1.92.

Paul Müller has determined[1] the resistivity of lead in the liquid state in the temperature range 327° C. to 1000° C. His value for the resistivity at 600° C. is 107.2 microhms, and our value at the same temperature is 107.2_5 microhms, a difference of less than 0.1 of 1 per cent.

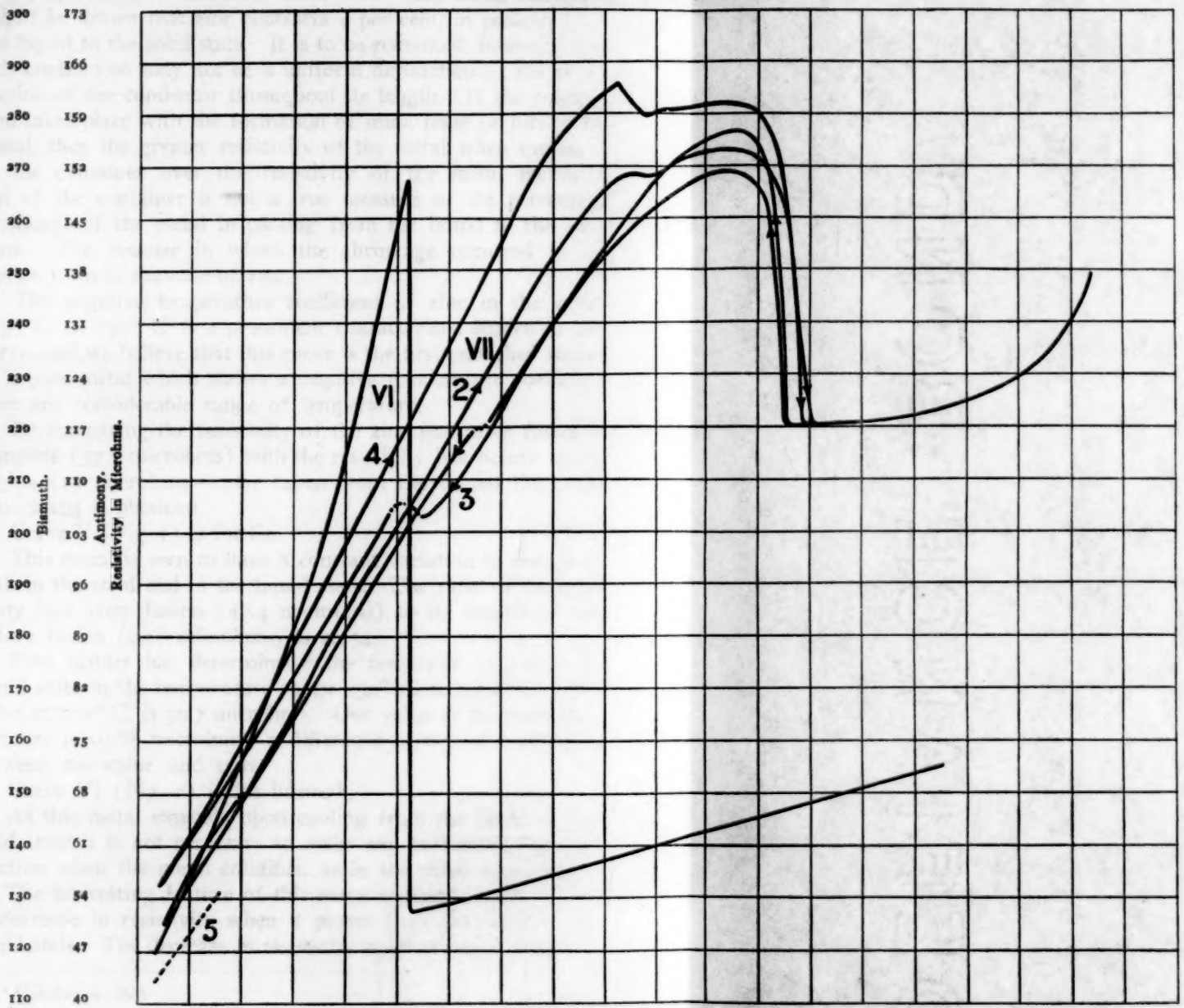
Curve IV (Fig. 1) is for zinc.

All the remarks which apply to shrinkage in the case of cadmium apply equally in the case of zinc. A curve is drawn in dotted line parallel to the curve in full line to express the resistivity of zinc in its solid state. The curve is drawn through points at 18° C. and 100° C. The published value at 100° C.

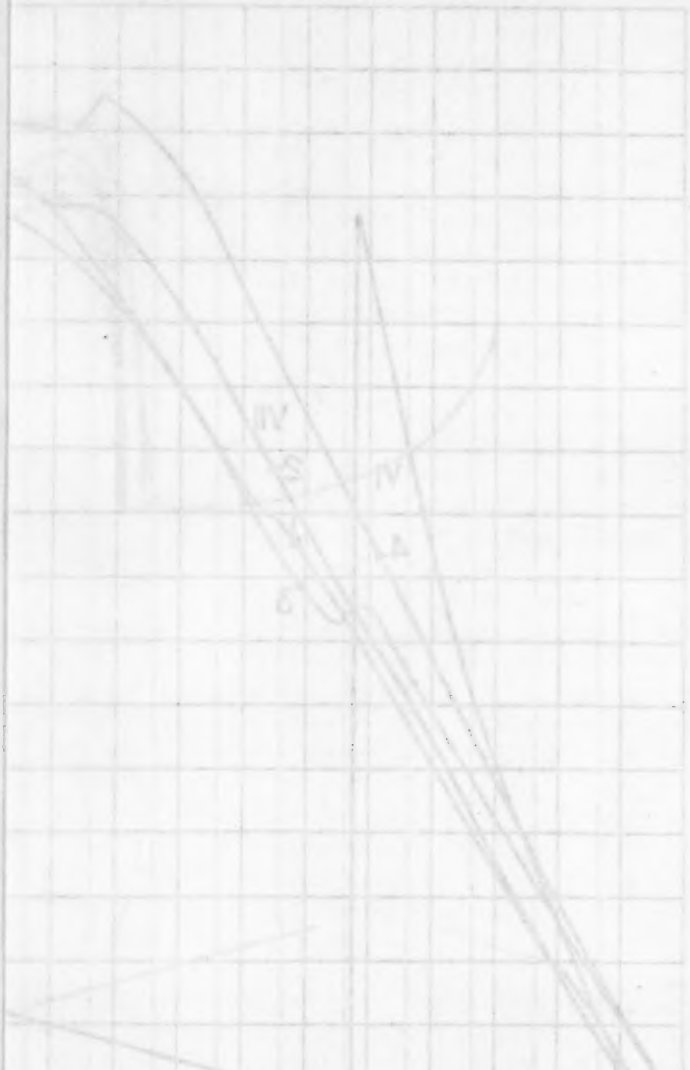
[1] *Metallurgie*, Halle, 7, pp. 730–755, Nov., 1910.

FIG. 2.

VI. Bismuth, Dec. 20–22, 1912.
VII. Antimony, Dec. 28, 1912–Jan. 8, 1913.



Observers :—E. P. Northrup and V. A. Suydam.



is 4 per cent. lower than our value. The conclusion, therefore, might be drawn that zinc contracts 4 per cent. in passing from the liquid to the solid state. It is to be remarked, however, that this contraction may not be a uniform diminution of the cross-section of the conductor throughout its length. If the contraction takes place with the formation of small holes or pits in the metal, then the greater resistivity of the metal when measured in the container over the resistivity of the metal measured out of the container is not a true measure of the percentage shrinkage of the metal in passing from the liquid to the solid state. The manner in which the shrinkage occurred is not known to us in the case of zinc.

The negative temperature coefficient of zinc in the range 427° C. to 750° C. is a prominent characteristic shown in this curve, and we believe that this curve is the first published record of a pure metal which shows a negative temperature coefficient over any considerable range of temperature.

By comparing the resistivity of the zinc just after fusion is complete (37.3 microhms) with the resistivity just before fusion begins (17 microhms—value taken from the dotted line), the ratio 2.194 is obtained.

Curve V (Fig. 1) is for tin.

This metal is seen to have a constant variation in resistivity both in the solid and in the liquid state. The ratio of its resistivity just after fusion (47.4 michroms) to its resistivity just before fusion (22.0 microhms) is 2.154.

Paul Müller has determined [2] the resistivity of tin in its liquid state in the temperature range 232° C. to 1000° C. His value at 700° C. is 59.7 microhms. Our value at the same temperature is 59.88 microhms—a difference of 0.3 of 1 per cent. between his value and ours.

Curve VI (Fig. 2) is for bismuth.

As this metal expands upon cooling from the liquid to the solid state it is not necessary to make any correction for contraction when the metal solidifies, as in the other cases above.

The interesting feature of this curve is that bismuth is seen to decrease in resistivity when it passes from the solid to the liquid state. The decrease in resistivity is exceedingly abrupt.

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[2] *Metallurgie*, ibid.

The resistivity just before fusion is 267 microhms, so far as we have any knowledge, the highest resistivity of any pure metal. The resistivity just after fusion is 127.5 microhms. The ratio of the former to the latter is 2.09.

The curve is slightly convex toward the temperature axis while the metal is in the solid state, and is a straight line while it is in the liquid state.

Curves VII (Fig. 2) are for antimony.

These curves represent four determinations made with the same sample—two made with falling temperature and two with rising temperature. Arrows are marked upon the curves to indicate which determinations were made with rising temperature and which with falling. In runs 1, 2 and 3 the temperature was raised to 750°C., but in the fourth run the temperature was raised to 915° C., when indications were given of the formation of a bubble of vapor—not a bubble of gas, because on lowering the temperature the resistivity returned to the same value (around 800° C.) as was previously observed.

The curves for antimony all come together very exactly when the metal has passed completely into its molten state. This fact, together with the great care exercised throughout the measurement, leads us to believe that the wide departures and the inflexions in the curves where they express the resistivity in the solid state represent true physical phenomena. Antimony crystallizes and probably assumes in the container, above a certain temperature, an amorphous condition. These facts very probably account for the wide variations in the resistivities as observed in the solid state in the different determinations. The resistivity was obtained by measuring a cast rod of the same specimen as that studied in the container. In order to obtain the rod the antimony was melted in a graphite crucible and cast in a graphite mould. The crystalline structure of this sample was observed to be very different from that of a sample taken from the container and which had cooled from the liquid state with extreme slowness. The results of this determination are shown by the dotted line 5, Fig. 2. The value obtained at 20° C. was 43.47 microhms per centimeter-cube. W. Haken's value [3] at 18° C. is 43.48, and estimated for 20° C. is 43.65 microhms.

[3] *Ann. Physik* (4), 32, 336.

We shall reserve to a later report our further discussion of the peculiarities of this erratic substance. We hope to secure additional infomation which will help to clear up the causes of the irregular behavior of antimony in its solid state.

We give below a short table of some of the values found by us for the resistivities of the above substances at different temperatures:

Cadmium		Lead		Zinc	
Temperature in degrees C.	Resistivity, microhms per cm.-cube	Temperature in degrees C.	Resistivity, microhms per cm.-cube	Temperature in degrees C.	Resistivity, microhms per cm.-cube
300	16.52	319	50.00	415	17.00
325	33.76	333	95.00	427	37.30
350	33.60	400	98.30	450	37.08
400	33.70	450	100.55	500	36.60
450	33.90	500	102.85	550	36.20
500	34.12	550	105.05	600	35.90
550	34.44	600	107.25	650	35.72
600	34.82	650	109.51	700	35.60
650	35.26	700	111.75	750	35.59
700	35.78	750	114.00	800	35.60
		800	116.20	850	35.74

Tin		Bismuth		Antimony	
Temperature in degrees C.	Resistivity, microhms per cm.-cube	Temperature in degrees C.	Resistivity, microhms per cm.-cube	Temperature in degrees C.	Resistivity, microhms per cm.-cube
225	22.00	17.5	120.00	627	117.00
235	47.60	100	156.50	650	117.07
300	49.44	150	181.65	700	117.65
350	50.76	200	214.50	750	118.53
400	52.00	259	267.00	800	120.31
450	53.30	263	127.50	850	123.54
500	54.62	300	128.90	900	131.00
550	55.94	350	131.55		
600	57.22	400	134.20		
650	58.58	450	137.00		
700	59.88	500	139.90		
750	61.22	550	142.50		
		600	145.25		
		650	148.00		
		700	150.85		
		750	153.55		

PALMER PHYSICAL LABORATORY,
PRINCETON, N. J., Jan. 17, 1913.

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PALMER PHYSICAL LABORATORY,
PRINCETON, N. J., Jan. 17, 1913.

Ductile Tungsten. C. G. FINK. (*Eighth Int. Congr. of Appl. Chem.*, 1912.)—A description of the properties and uses of ductile tungsten. Some of the applications mentioned are the use of tungsten wire gauze for separating solids from acid liquors, etc.; the use of the metal for standard weights, acid-proof dishes and tubes, watch-springs, etc., and in conjunction with molybdenum for thermo-couples, *e.g.*, for measuring high temperatures in the "tungsten-hydrogen furnace." The electromotive force of the couple increases with the temperature up to 540° C. 12½ millivolts, then decreases, and becomes *nil* at about 1300° C.

No Substitute for Tin. ANON. (*Brass World*, viii, 12, 420.)—The present high price of tin reminds us that there is no substitute for this metal in practically all its uses. The manufacture of tin plate takes most of it; the consumption in tin cans for containing food is enormous, and there is no substitute. There is no substitute for tin in bronze and composition castings, and it is indispensable in order to obtain the absolutely necessary casting qualities and hardness. There is an enormous consumption of solder, which cannot be made without tin. There is no substitute for either tin or copper, and it is difficult to see how we could get along without either of them.

Action of Water and Sodium Hydroxide on Cotton Cellulose. M. ROBINOFF. (*Papierfabr.*, x, 968.)—This is a study of the behavior of cotton toward dry heat, water at high temperatures, dilute acids, and dilute and concentrated sodium hydroxide. The chief conclusion is that cellulose which has become modified in the course of industrial chemical treatments possesses totally different properties from normal cellulose. Normal cellulose is extremely resistant, and is only slightly modified when boiled with water under pressure. On the other hand, cellulose which has been subjected to boiling and bleaching processes is very considerably attacked by boiling water under pressure, especially at temperatures above 150° C., and is completely broken down to hydro-cellulose when digested under a pressure of 20 atmospheres. Duration of treatment has no appreciable influence, apparently. Cold and hot (up to 100° C.) dilute sodium hydroxide lyes have no effect on the structure or chemical properties of cellulose, but these lyes have great effect at higher temperatures. A concentration of 4 per cent. sodium hydroxide appears particularly dangerous. Duration of action has little effect. In souring after bleaching, it appears that dilute acids act more energetically on the cellulose than acid of double or quadruple strength. Acetic acid seems to have as much action as hydrochloric acid. Normal Egyptian cotton, after treatment in the heating engine for four hours, showed an increase in hygroscopic moisture, copper value, and hydrolysis value.

NOTES FROM THE U. S. BUREAU OF STANDARDS.

LEGAL SPECIFICATIONS FOR ILLUMINATING GAS.

By E. B. ROSA, Chief Physicist, and R. S. McBRIDE, Assistant Chemist, Bureau of Standards.

THE revision of the Bureau of Standards Circular No. 32 on "State and Municipal Regulations for the Quality, Distribution, and Testing of Illuminating Gas" was discussed before the American Gas Institute in connection with the presentation of this paper. A consideration of relative merits of candle-power and heating value regulations as the basis of the legal specifications for gas quality indicates the greater advantage of the heating value standard as the principal basis for the regulations; however, it will be best in general to retain a candle-power limit in municipal ordinances for the protection of open-flame burner users. The candle-power limit should be so low as to be less than the value which will ordinarily be met by present-day methods, in order that no undue expense of manufacture will result from its presence in the law. In effect, it will serve only to hold gas manufacture along present methods until it is shown that other methods operate to the advantage of the gas user, and it thus prevents changes in manufacture profitable to the company without a new basis of specification which will ensure that the customer is given some advantage in the change.

A full discussion of the "net" and "total" heating values indicates the significance of each and concludes that either may be used with perfect fairness and without uncertainty. A new method of computing the total heating value by correction for the latent heat of the water vapor carried out of the calorimeter is indicated; this method is recommended for general adoption in official testing where an accuracy of greater than two per cent. is needed.

Some errors in the current method of calculation of candle-power of gas are indicated. These are very large in cities of high altitude. No entirely satisfactory means of eliminating this irregularity is at present available, but further work on this subject is promised by the Bureau, with the idea of gather-

ing such data as will permit a fairer and more satisfactory system of gas candle-power rating.

The use of an open-flame test burner for gas candle-power measurements is again recommended; and a number of the phases of gas quality regulation are briefly discussed.

A SIMPLIFIED FORMULA FOR THE CHANGE IN ORDER OF INTERFERENCE DUE TO CHANGES IN TEMPERATURE AND PRESSURE OF AIR.[1]

By IRWIN G. PRIEST, Assistant Physicist.

THE author developed independently for use at the Bureau of Standards the following correction formula:

$$K = \left(\frac{b_1}{1 + at_1} - \frac{b_2}{1 + at_2}\right) l \left[\frac{\omega - 1}{380\lambda}\right]$$

where t_1 = lower temperature Centigrade
t_2 = higher temperature Centigrade
b_1 = pressure in mm. of mercury at temp. t_1
b_2 = pressure in mm. of mercury at temp. t_2
l = distance between mirrors
ω = refractive index at 0°, 760 mm.
a = coef. of expan. of air
λ = wave-length.

He noticed later that the formula published by Pulfrich,[2] viz.:

$$K = l(t_2 - t_1)\frac{b_1}{760} \cdot \frac{1}{1 + at_1} \cdot \frac{1}{1 + at_2}\left[\frac{2(\omega - 1)a}{\lambda}\right]$$

$$- l(b_2 - b_1) \cdot \frac{1}{1 + at_2}\,\frac{2(\omega - 1)}{760\lambda}$$

could be reduced to this simpler and more convenient form. The derivation of the new formula is given and the two formulas are compared as to convenience in practice.

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[1] To understand this abstract the reader must see first Pulfrich, *Zeit. für Inst. K.* 13, 456.

[2] The sign in Pulfrich's paper is in error if the expression is to give the *correction*, not the *error*.

THE DENSITY AND THERMAL EXPANSION OF ETHYL ALCOHOL AND ITS MIXTURES WITH WATER.[1]

By N. S. OSBORNE, E. C. McKELVY, and H. W. BEARCE.

PART I deals with the preparation of pure ethyl alcohol. Ethyl alcohols from different sources were subjected to purification treatments. The lower boiling impurities were completely removed by heating the alcohol for a considerable time under a reflex condenser, the water of which was held at about 60° C. Dehydration was accomplished by means of lime, aluminum amalgam, and metallic calcium, giving an alcohol of nearly identical physical properties. The first two gave equally good results. The density values obtained with metallic calcium were somewhat higher. The physical properties used as criteria of purity were the density and the critical solution temperature of alcohol-kerosene mixtures (Crismer). These two methods are of approximately equal sensitiveness. An alcohol was obtained which when subjected to an additional dehydration and fractionation gave alcohol of the same density and with no separation into fractions of different densities. Dehydration and subsequent fractionation under reduced pressure gave alcohol of essentially the same density. These results indicate that the alcohol was pure within the limits set by the accuracy of determination of the physical constants used as criteria of purity. Dissolved acetic aldehyde increased the density, while ethyl ether and air decreased it.

The low results obtained for the density of anhydrous ethyl alcohol by Messrs. Squibb could not be obtained by a repetition of their procedure. A repetition of the procedure of Mendeléef gave results closely agreeing with his. Tables are given showing the comparison of results with those of former investigators. The mean density of fifteen of the fractions regarded as the purest was found to be 0.78506, at 25° C.

In Part II is reported the investigation upon the thermal expansion of mixtures of ethyl alcohol and water. Twelve mixtures of alcohol and water were prepared and their densities at 10°, 15°, 20°, 25°, 30°, 35°, and 40° C. determined by the

[1] Scientific Paper No. 197, from Bulletin of the Bureau of Standards, vol. 9.

method of hydrostatic weighing. The observations of density for each mixture were reduced by the method of least squares and the coefficients of the assumed equation

$$D_t = D_{25} + \alpha(t-25) + \beta(t-25)^2 + \gamma(t-25)^3$$

determined. The values of D_{25}, α, β and γ for the twelve mixtures are shown in Table I.

TABLE I.

Per cent. Alcohol by Weight	Density at 25° C.			
	g/ml	$\alpha \times 10^7$	$\beta \times 10^8$	$\gamma \times 10^{10}$
0.000*	0.997077	−2565	−484	+319
4.907	0.988317	−2684	−502	+311
9.984	0.980461	−3119	−484	+258
19.122	0.967648	−4526	−393	+180
22.918	0.962133	−5224	−331	+100
30.086	0.950529	−6431	−226	+ 47
39.988	0.931507	−7488	−145	− 4
49.961	0.909937	−8033	−128	− 24
59.976	0.887051	−8358	−121	− 24
70.012	0.863380	−8581	−117	− 9
80.036	0.839031	−8714	−108	− 69
90.037	0.813516	−8746	− 93	− 51
99.913	0.785337	−8593	− 57	− 62

* Water according to Chappuis.

The values of α, β and γ for each integral per cent. of alcohol between 0 and 100 were then obtained by interpolation.

Part III treats of the density of ethyl alcohol and its mixtures with water. The mean of fifteen determinations of the density at 25° C. of the purest alcohol obtained was found to be 0.78506 gram per millilitre. A series of twenty-five mixtures of known percentages of alcohol and water were prepared as close as possible to integral per cents and their densities at 25° C. determined, partly by the method of hydrostatic weighing and partly by the use of special picnometers; the same constant temperature bath being used in both methods. The densities of the various mixtures, reduced to the nearest integral per cent., are shown in Table II. The values for 90 and 95 per cent. are each the mean results of two mixtures.

TABLE II.

Per cent. Alcohol by Weight	Density (*) at 25°C. g/ml	Per cent. Alcohol by Weight	Density at 25° C.
0	0.997077	55	0.898502
2	0.993359	60	0.886990
5	0.988166	65	0.875269
6	0.986563	70	0.863399
10	0.980434	75	0.851336
15	0.973345	80	0.839114
20	0.966392	85	0.826596
25	0.958946	90	0.813622
30	0.950672	95	0.799912
35	0.941459	98	0.791170
40	0.931483	99	0.788135
45	0.920850	100	0.785058
50	0.909852		

* These density values are for mixtures saturated with air.

Tables I and II permit the calculation of the density of any mixture of ethyl alcohol and water at any temperature between 10° and 40° C. (Circular No. 19, Bureau of Standards).

Part IV describes a second and independent series of mixtures of known percentages of alcohol and water which were prepared and their densities determined at 15° and 25° C., thus furnishing, at the same time, a check on both the density at 25° and the change of density between 15° and 25°.

BUREAU OF STANDARDS.

DURING the fiscal year 1911-12 the activities of the Bureau resulted in a larger number of published papers than heretofore. The results of 35 scientific and technologic investigations were issued. The staff consisted of 192 scientific and other assistants, of whom about 80 were engaged upon special researches and investigations specially authorized by Congress. About 73,196 tests were made in addition to the researches completed and in progress during the year. The inspection work at the factories was developed for both cement and electric lamps, about 2,000,000 barrels of cement being sampled and 1,000,000 electric lamps inspected at the factories. The development of standard specifications for various materials has proceeded steadily in co-

operation with the national technical societies and the various departments of the Government. These will go far toward establishing definite standards of quality based upon the measured properties of the materials involved and thus benefit alike the manufacturer and the user of the materials. As heretofore, the demands for special investigations connected with standards, methods of measurement, and the properties of materials are more than can be met with the assistants available. The Bureau has been constantly called upon as referee and consultant by various departments of the Government, and for information and aid by public-service corporations and public-utilities commissions. As far as possible it has responded to these requests.

Antiseptic Tests of Wood-preserving Oils. A. H. DEAN and C. R. DOWNS. (*Eighth Int. Cong. Appl. Chem., Sect. VIa, Orig. Comm.*, xiii, 103.)—From the results of the author's experiments with *Polystictus versicolor*, the commonest of the wood-rotting fungi, it is evident that coal tar creosote is a stronger antiseptic than water-gas tar creosote, and that the latter is distinctly more effective than the liquid oil of the anthracene fraction of coal tar. The greater value of the coal tar oil appears to depend upon the presence of the tar acids, and especially on the tar bases. Water-gas tar creosote was found to be almost identical in antiseptic power with the coal tar oil with its tar acids removed. Alleman has shown that the oils remaining in wood treated with coal tar creosote are almost free from tar acids after a few years of service, and that under conditions allowing evaporation the lighter hydrocarbons are nearly all lost. Loss of antiseptic power from the disappearance of the tar acids cannot take place with water-gas tar oils, since they are free from phenols in the beginning. Since the amount of creosote injected into wood is usually 10 pounds or more per cubic foot, the difference in antiseptic power between coal tar oils and water-gas tar oils does not appear to be of much significance, particularly as the tar acids tend to disappear from the wood treated with coal tar oil. It is considered that water-gas tar creosote has a distinct value for the preservation of wood.

THE FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting held Wednesday, January 15, 1913.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 15, 1913.

PRESIDENT WALTON CLARK *in the Chair.*

Additions to membership since last report, 10.

The tellers, Messrs. Colvin, Cullen, and Jennings, submitted the report of the ballots cast for President, Vice-President, Treasurer, and members of the Board of Managers.

The following gentlemen were declared duly elected to the respective offices:

Walton Clark, President (to serve one year).

Henry Howson, Vice-President (to serve three years).

Cyrus Borgner, Treasurer (to serve one year).

Francis T. Chambers, W. C. L. Eglin, Alfred C. Harrison, Charles A. Hexamer, Robert W. Lesley, Robert S. Perry, E. H. Sanborn, Managers (to serve three years).

The President presented a statement of the work of the Institute during the past year.

Following the meeting of the Institute for the transaction of this business, the Chairman introduced Mr. Elmer A. Sperry, of The Sperry Gyroscope Company, New York City, who presented a communication on the "Applications of the Gyroscope to Marine Purposes."

After a brief reference to the theory of the gyroscope, its applications as a marine compass were discussed at length, and the advantages of the gyrostatic compass over the magnetic compass, particularly for naval purposes, were pointed out. The practical application of the gyroscope to the stabilizing of marine and aërial craft was also fully considered and specific instances described.

The subject was illustrated by numerous lantern slides and working models.

After a brief discussion the thanks of the meeting were extended to the speaker, the subject was referred to the Committee on Science and the Arts for investigation, and the paper was referred to the Committee on Publications.

Adjourned.

R. B. OWENS,
Secretary.

REPORT OF THE BOARD OF MANAGERS FOR THE YEAR ENDING SEPTEMBER 30, 1912, WITH APPENDICES EMBRACING THE ANNUAL REPORTS OF THE VARIOUS COMMITTEES AND SECTIONS.

To the Members of The Franklin Institute:

The Board of Managers formally present herewith the reports of the standing committees of the past year. These reports have been printed, and copies will be sent to the members. The Board hope that you will learn from these reports that the work of the Institute was pushed with vigor during the year 1912, and is to-day in a condition satisfactory to you.

The Committee on Instruction again report an increase in the enrolment of students and in the number of graduates. The extensive improvements that have been made to the school rooms, rendering them more sanitary, more convenient, and otherwise more attractive with the close attention given to the educational affairs of the Institute by the Committee on Instruction and by the faculty, are being more and more appreciated by young men seeking to better their education through night work.

The report of the Committee on Election and Resignation of Members shows an increase in the number of members elected during the year of over 100 per cent., as compared with the previous year. The Institute is slowly growing in numbers.

The Board call your especial attention to the report of the Committee on Publications, in which you will find a list of men who have consented to act as Associate Editors of the JOURNAL. Each of these men is recognized as an authority, many without a peer, in his particular field of work. It would be difficult to exaggerate the importance to the JOURNAL and to the scientific world of this association. The Year-Book of the Institute for the current year, gotten out by the Committee on Publications, is a valuable document for any one interested in the affairs of the Institute.

The Committee on Sectional Arrangements report as usual a successful year.

The Endowment Committee report that since the opening of the fiscal year the Institute has received an endowment of $50,000 from a friend of the Institute, as a memorial of the late James H. Cresson, a former member. This fund is to be kept intact, and the interest upon it is at the disposal of the managers for use in the work of the Institute. Within the past eighteen months nearly $200,000 have been added to the endowment funds of the Institute, in the care of our Board of Trustees.

The Committee on Library report a large increase in the number of books and pamphlets in the library.

For the first time in many years, we have an important report from

the Committee on Museums. We call this to your especial attention, and we hope that many members of the Institute will make it convenient to visit the building, during the daytime, and examine the many beautiful models that the Committee on Museums have recently placed on exhibition. Some of these are exceedingly valuable historically, and each is an example of the finest product of the model maker's skill.

The report of the Committee on Science and the Arts is, as always, interesting, and shows that the work of the committee is well kept up. Medals have been awarded this year to some of the most distinguished scientists of the world, and have been received with expressions of high appreciation.

Your Board have great pleasure in calling your attention to the improvement in the financial condition of the Institute. Although our income from dues and endowment is still less than our expenditures in the prosecution of the Institute's work, the difference is now gradually diminishing from year to year.

The Building Fund still grows slowly, and we cannot venture to prophesy when it will be sufficient to justify us in the purchase of land and the erection of a new building. In the meantime, these old walls, which have echoed in their day the voices of the foremost scientists of the world, and are still, from month to month, sheltering guests who bring to us the best scientific thought of the world, are proving sufficient to our needs, though, through their relatively inaccessible location, somewhat limiting the usefulness of our activities to the citizen and to the State.

Respectfully submitted for the Board of Managers.

WALTON CLARK,
President.

PHILADELPHIA, January 8, 1913.

REPORT OF THE COMMITTEE ON INSTRUCTION.

To the Board of Managers:

The 88th year of the School of the Institute, and the second year of the Franklin Institute School of Mechanic Arts as reorganized, opened in September, 1911, with an enrolment of 249 students, an increase of 43 over the preceding year.

The faculty of the school for the year 1911–1912 was as follows:

Professor William H. Thorne, Director, in charge of the Department of Drawing.

Professor Clement Remington, in charge of Architectural and Freehand Drawing.

Messrs. A. T. Klein, I. P. Pedrick, and W. W. Twining, Assistants in Mechanical Drawing.

Professor William E. Bullock, Assistant Director, in charge of the Department of Mechanics.

Professor H. P. Tyson, in charge of the Department of Mathematics.
Mr. R. R. Umstead, Instructor in Mathematics.
Professor H. C. Towle, in charge of the Department of Naval Architecture.

The plan of instruction in the four departments was that adopted at the reorganization of the school two years ago; and the increased registration in all the departments, the improved attendance, and the excellence of the work done appear to justify an adherence to this schedule for the coming year.

The graduating exercises were held in the Hall of the Institute on the evening of April 19, 1912. An address to the graduates was given by Director Morris L. Cooke, of the Department of Public Works, his remarks being on the importance of a technical education from a practical standpoint.

At these exercises thirty-nine students were graduated from the school. Fourteen of these received certificates for Mechanical Drawing, five for Architectural Drawing, four for Freehand Drawing, eight for Mathematics, two for Mechanics, and six for Naval Architecture.

Certificates are in each case awarded on the completion of two years of prescribed work. Their number in Mathematics and Mechanics is usually small in proportion to the registration in any one term on account of the fact that many students enter these departments with the intention of following only partial courses.

Increased facilities have been given the students for studying the historical aspect of engineering by having a large number of the Institute models transferred to the school rooms.

Lectures delivered at stated meetings of the Institute and before the Institute's Sections are open to students of the school. Many of these lectures delivered during the past year were of especial interest to the members of the school, and were well attended by them.

It is hoped that the combined advantages from attending these lectures and from membership in the Alumni Association may increase the interest of the students in the other lines of work carried on by the Institute.

The calendar for 1912–1913 was drawn up on the lines of the two previous issues. A programme of visits to engineering works in and about Philadelphia, arranged for the new season, was included, together with several examples of work done in the school in the preceding year. Announcement was made of a gift by the New York Shipbuilding Company of a valuable set of drawing instruments, to be awarded to the student of greatest merit in the Department of Naval Architecture.

The increased advertising afforded by the new calendar, enlarged to contain more specific information on, and syllabi of, the work, in the various departments, undoubtedly accounts in some measure for the augmented enrolment in the present year. To date a total of 286 students have been registered for the season just commenced, an increase of 37 students over the enrolment of last year. The registration figures for the last three years are included here for comparison:

	Winter Term.				Spring Term.			
	1909–1910.	1910–1911.	1911–1912.	1912–1913.	1909–1910.	1910–1911.	1911–1912.	1912–1913.
Drawing	98	140	138	158	67	112	116	..
Mathematics	41	37	63	61	18	29	32	..
Mechanics	22	24	28	38	18	21	20	..
Naval Architecture	12	5	20	29	8	5	16	..
	173	206	249	286	111	167	184	..

Respectfully submitted,

For the Committee,
GEORGE A. HOADLEY.

LAWRENCE T. PAUL,
Chairman.

PHILADELPHIA, January 8, 1913.

REPORT OF THE COMMITTEE ON ELECTIONS AND RESIGNATIONS OF MEMBERS.

To the Board of Managers:

During the fiscal year ending September 30, 1912, there were one hundred and ten new members enrolled; resignations were received and accepted from forty-one members, and deaths were recorded of twenty-six members.

The figures for the several classes of membership, with the preceding year for comparison, follow:

Elections:	1910–11.	1911–12.
Resident Members	28	68
Non-Resident Members	15	33
Associate Members	5	7
Honorary Members	0	1
Life Members	4	1
	52	110

Resignations:	1910-11.	1911-12.
Resident Members	12	27
Non-Resident Members	12	13
Associate Members	0	1
	24	41

Deaths:	1910–11.	1911–12.
Resident Members	16	9
Non-Resident Members	5	4
Life Members	9	11
Honorary Members	0	1
Corresponding Members	0	1
	30	26

Respectfully submitted,

W. C. L. EGLIN,
Chairman.

PHILADELPHIA, January 8, 1913.

REPORT OF THE COMMITTEE ON STOCKS AND FINANCE.

Financial Statement, October 1, 1911, to September 30, 1912.

PROPERTY AND FUNDS.

Building and land, 13–17 S. Seventh Street		$60,000.00	
Library		100,000.00	$160,000.00
	Principal.	Unexpended Income.	
Funds held by Board of Trustees	$213,289.10	$96.17	
Funds held by Board of Managers	23,478.50	45.33	
Franklin Institute Building Fund	360,080.22	.....	
Elliott Cresson Medal Fund	1,000.00	2,405.52	
Franklin Fund and Building Committee	4,368.30	.....	
Total funds	$602.216.12	$2,547.02	$604,763.14
Grand total			$764,763.14

LIABILITIES.

Certificates of stock	$30,420.00
Mortgage on Institute Building (held by Trustees as investment for funds)	22,075.00
Bills payable	16,250.00
Accounts payable	4,525.14
Unearned income	943.51
Grand total	$74,213.65

INCOME AND EXPENSES APPLICABLE TO YEAR ENDING SEPTEMBER 30.

Income.

Dues		$8,777.97
Initiation fees		135.00
General Endowment Fund		6,518.21
Estate of John Turner		136.03
Estate of Robert Wright		1,801.69
Miscellaneous		.29
Membership badges		5.20
Instruction: Drawing	$1,253.50	
Mathematics	471.00	
Mechanics	240.00	
Naval Architecture	270.00	2,234.50
Publications: Subscriptions and sales	$1,800.89	
Advertising	2,945.61	4,746.50
Total		$24,355.39

Expenses.

Building: Wages	$1,019.93	
Repairs and maintenance	318.58	
Heat, light, and power	699.85	
Taxes, water rent, and insurance	809.22	
Miscellaneous supplies and expense	243.59	$3,091.17
Elections and resignations		32.97
Instruction: Drawing	$1,010.50	
Mathematics	237.82	
Mechanics	155.91	
Naval architecture	220.00	
Miscellaneous expense	494.50	2,118.73
Library: Salaries	$3,567.10	
Books and periodicals	1,672.81	
Binding	727.50	
Miscellaneous expense	479.31	6,446.72
Meetings		414.65
Office and General: Salaries	$7,177.12	
Office expense	724.10	
General expense	1,082.03	8,983.25

Publications: Printing		4,863.30	
Reprints		136.00	
Illustrating		390.48	
Miscellaneous expense		478.37	
Year-Book		488.38	6,356.53
Science and Arts			1,156.50
Sections			715.75
Interest and discount			840.38
Model repairs			78.17
Interest paid John T. Kille on donation to General Endowment Fund			200.00
Total			$30,434.82
Net expense			6,079.43

During the fiscal year there has been an increase in funds as follows:

General Endowment Fund	$148,105.21
Elizabeth M. Graff Fund	16.79
Franklin Institute Building Fund	8,651.62
Franklin Fund and Building Committee	85.73

The large increase in the General Endowment Fund was principally caused by the Noblit bequest of $135,822.79, and the Blanchard bequest of $10,000.

The mortgage on the Institute building has been increased by $19,250. Bills payable have been decreased by $12,000.

The excess of expense over income for the year was $6,079.43. This deficit was due to outlays required to maintain the Institute in its present condition of affording satisfactory service to its members and the public.

Respectfully submitted,

WALTON FORSTALL,
Chairman.

PHILADELPHIA, January 8, 1913.

REPORT OF THE COMMITTEE ON PUBLICATIONS.

(*Abstract.*)

To the Board of Managers:

Two principal features mark the activity of the Institute in the matter of its publications during the past year. The most important of these is the assistance obtained by the Committee on Publications in the editorial management of the JOURNAL, a function which, in the nature of things, could at best be performed but inadequately by the several members of the committee, and which, in point of fact, required the co-operation of specialists in all the various branches of science and technology.

To meet this requirement, the committee, under the guidance of the

Secretary, has organized a body of Associate Editors, the members of which, all of them recognized authorities in their respective fields of work, have graciously consented to collaborate with the Secretary, and, through that officer, with your committee, in the editorial direction of the JOURNAL. The list of our editorial associates is as follows:

Brigadier General James Allen, Chief Signal Officer U. S. Army, War Department, Washington, D. C.

John J. Carty, Chief Engineer, American Telephone and Telegraph Company, New York.

A. S. Cushman, Ph.D., Director, Institute of Industrial Research, Washington, D. C.

Louis Duncan, Ph.D., Consulting Electrical Engineer, New York City.

Harry C. Jones, Ph.D., Professor of Physical Chemistry, Johns Hopkins University, Baltimore, Md.

Harry F. Keller, Ph.D., Professor of Chemistry, Head of Department of Chemistry and Biology, Central High School, Philadelphia.

Alfred Noble, C.E., LL.D., Consulting Civil Engineer, New York City.

L. A. Osborne, M.E., Vice-President, Westinghouse Electric and Manufacturing Company, Pittsburgh, Pa.

Edgar F. Smith, Ph.D., Sc.D., LL.D., Provost, University of Pennsylvania, Philadelphia.

Major George Owen Squier, Ph.D., Military Attaché, American Embassy, London, England.

Charles P. Steinmetz, M.A., Ph.D., Consulting Engineer, General Electric Company; Professor of Electrical Engineering, Union College, Schenectady, N. Y.

S. W. Stratton, D.Eng., Sc.D., Director, Bureau of Standards, Washington, D. C.

Naval Constructor D. W. Taylor, U. S. Navy, Washington, D. C.

S. M. Vauclain, Sc.D., Vice-President, The Baldwin Locomotive Works, Philadelphia.

Edward Weston, Sc.D., LL.D., President, Weston Electric Instrument Company, Newark, N. J.

W. R. Whitney, Ph.D., Director, Research Laboratory, General Electric Company.

R. S. Woodward, C.E., Ph.D., Sc.D., LL.D., President, Carnegie Institution, Washington, D. C.

A. F. Zahm, M.E., Ph.D., Professor of Mechanics, Catholic University of America.

It may well go without saying that the assistance afforded us by these eminent scientists in the editorial management of the JOURNAL has proven to be invaluable in maintaining its contents at the standard of contemporary requirements, and also that it has been effective to the end in view.

In conformity with its recently-adopted regulations, the Committee on Science and the Arts, at its meeting in June last, certified its special appreciation of a number of the more important contributions to the pages of the JOURNAL during the preceding year by awarding to the respective authors the recognition of the Institute in the form of one or another of

the several medals at its disposal. No more fitting acknowledgment could well be made.

The second of the two main features of our past year's work is the publication of a Year-Book of the Institute in a form and of a quality commensurate with the dignity of a leading centre of scientific activity. Instead of a pocket edition of this publication, the committee, with the special consent of the Board, has issued this year's edition in full octavo form, which, by dint of painstaking effort on the part of the Secretary and his assistants, presents not only a completely revised directory of the membership of the Institute, but also a compendious statement of its organization and its various activities.

The cost of the Year-Book, which amounts to $488.38, has brought the total cost of our publications during the past year to some $1600 more than the immediate returns derived from them. Leaving out the Year-Book, for which special provision was made by the Board, there appears a debit balance of some $1100 on what is practically the JOURNAL account, an increase of $690 over the like deficit in the preceding year. Of this amount, some $336 is due to a falling off in the returns and the remainder to a higher cost of printing and incidentals.

In this connection, however, the committee takes occasion to point out that of the total amount of $6,300 appropriated for its requirements during the past fiscal year, a balance of $431.85 remained available at its close. This condition is accounted for by an unexpended balance in the appropriations for illustrations, reprints and miscellaneous expense, but has, of course, only a negative bearing on the actual debit balance of the committee's budget.

Respectfully submitted,

LOUIS E. LEVY,
Chairman.

PHILADELPHIA, January 8, 1913.

REPORT OF THE COMMITTEE ON SECTIONAL ARRANGEMENTS.

To the Board of Managers:

The Committee on Sectional Arrangements takes pleasure in reporting that the year ending September 30, 1912, has been an unusually satisfactory one from the standpoint of the interest displayed in the sectional meetings. It will be noted, from the accompanying description, that the roll of lecturers includes the names of many men of the highest standing in the scientific and professional worlds. This fact, together with the varied nature of the subjects presented and their scientific and practical importance, accounts in great measure, no doubt, for the largely-increased attendance at the meetings. We trust, however, that this increase in attendance also indicates a growing interest in the lectures at the Institute through the efforts of its members to spread its influence.

During the year just passed nineteen meetings have been held by the various sections, as follows:

PHYSICS AND CHEMISTRY SECTION.

Seven Meetings.

October 30, 1911.
Surface Combustion and Its Industrial Applications.
Prof. W. A. Bone.

November 9, 1911.
Some Electro-Chemical Experiments.
Dr. G. H. Meeker.

December 14, 1911.
Recent Developments in the Field of Physical Chemistry.
Prof. Harry C. Jones.

January 4, 1912.
Some Industrial Research Problems of Public Importance.
Mr. H. A. Gardner.

March 28, 1912.
The History, Properties, Preparation and Uses of the Rare Gases.
Dr. R. B. Moore.

April 11, 1912.
Platinum.
Dr. Harry F. Keller.

April 25, 1912.
The Chemical Defences of the Organism Against Disease.
Dr. Wm. J. Gies.

ELECTRICAL SECTION.

Three Meetings.

October 12, 1911.
Electrical Methods of Intercommunication for Military Purposes.
Major Geo. O. Squier.

February 15, 1912.
Alternating Current Development in America.
Mr. Wm. Stanley.

March 7, 1912.
Electrification on Main line Railways.
Mr. W. J. Clark.

PHOTOGRAPHIC SECTION.

Two Meetings.

October 5, 1911.
High Speed Night Photography.
Mr. G. Dietz.

March 8, 1912.
Symphany in Stereoscopic Radiography.
Dr. P. H. Eijkman, Scheveningen, Holland.

MECHANICAL AND ENGINEERING SECTION.

Four Meetings.

February 1, 1912.
Sun Power.
Mr. Frank Shuman.

February 8, 1912.
Improvements of Our Rivers and Harbors.
Prof. Lewis M. Haupt.

February 29, 1912.
Roads and Pavements and Their Materials of Construction.
Mr. Prevost Hubbard.

April 4, 1912.
Electropneumatics as Applied to Train Control.
Mr. Walter V. Turner.

MINING AND METALLURGICAL SECTION.

Two Meetings.

October 26, 1911.
A Practical Application of Fluorescence in Testing Oils for Industrial Purposes.
Prof. A. E. Outerbridge, Jr.

April 19, 1912.
Natural Gas.
Mr. I. N. Knapp.

SECTION OF AËRIAL NAVIGATION AND AËRONAUTICS.

One Meeting.

January 25, 1912.
Aëronautic Laboratories, Their Establishment and Operation.
Dr. A. F. Zahm.

The meeting of the Section of Aërial Navigation and Aëronautics was the inaugural meeting of this Section.

Most of the lectures were illustrated by lantern slides, and at some of them practical demonstrations were given and exhibits shown.

A number of lectures have also provided most excellent material for the JOURNAL.

CHARLES DAY,
Chairman.

PHILADELPHIA, January 8, 1913.

REPORT OF THE COMMITTEE ON ENDOWMENT.

To the Board of Managers:

Your committee reports that two endowments were received during the fiscal year ending September 30, 1912, covered by this report: one for $133,822.79, which was received from the estate of the late Joseph H. Noblit, of Philadelphia, and the other for $10,000, which was received from the estate of the late Miss Maria Blanchard, also of Philadelphia.

Both of these endowments were mentioned in the last annual report of the President.

Your committee also reports having received, since the opening of the fiscal year, an endowment of $50,000 from a friend of the Institute as a memorial to the late James H. Cresson, formerly a member of The Franklin Institute.

Your committee believes that, if the members of the Board of Managers would bring the question of endowment to the attention of their friends and others who are interested in the Institute or in the mechanic arts, the needs of the Institute would be given greater publicity.

In the future, when the new building is erected, a large endowment will be necessary to carry on the work of the Institute.

Respectfully submitted,

HENRY HOWSON,
Chairman.

PHILADELPHIA, January 8, 1913.

REPORT OF THE COMMITTEE ON LIBRARY.

(Abstract.)

To the President and Members of The Franklin Institute:

The Committee on Library begs to submit the following report on the activities of the Library during the twelve months ending September 30, 1912:

The additions made to the Library during this period are as follows:

Source.	Bd. Vols.	Unb. Vols.	Pphs.	Maps.	Drawings.	Photos.
Gift	293	487	696		1	24
Exchange account	21	12	6			
JOURNAL	35	24	108	1		
Binding: Institute Appropriation	382					
Chemical Periodicals Binding Fund	26					
Moore Fund	2					
Morris Fund	158					
Institute Appropriation	86	12	3	1		
Lea Fund	128	15	1			
Memorial Library Fund		2				
Moore Fund	338	51				
Morris Fund	40	7				
Potts Fund	8	3				
	1,517	613	814	2	1	24

Total additions for the year, 2,971, being an increase of 871 over the previous year.

Gifts of books, pamphlets, and periodicals in large quantities or of special value were received as follows:

Mr. Hugo Bilgram, copies of technical magazines and society publications.

Mr. Max Freimark, volumes and pamphlets on engineering subjects.

Mr. F. Lynwood Garrison, copies of technical magazines.

Dr. Carl Hering, bound volumes and pamphlets on electrical subjects, and a set of the reports of the juries of the Paris Exposition of 1900.

Dr. Samuel C. Hooker, volumes, pamphlets, and numbers of magazines on chemistry and related subjects.

Mr. Henry Howson, copies of technical magazines.

Robert D. Jenks, Esq., bound volumes and numerous pamphlet reports of railroad companies and State railroad commissions.

Mr. S. Howard Rippey, copies of technical magazines.

Mr. Henry Steck, books on gas manufacture.

Dr. W. H. Trueman, copies of technical magazines.

Messrs. Cope & Stewardson, copies of recent issues of architectural publications.

Crocker-Wheeler Company, Philadelphia, copies of trade papers and engineering periodicals.

The Engineers' Club of Philadelphia, copies of engineering publications for the year 1911.

The Geographical Society of Philadelphia, copies of recent geographical and scientific publications and society transactions.

Messrs. Harris & Richards, volumes, pamphlets, and magazines on architecture and engineering.

The Pennsylvania Railroad Company, pamphlet reports of its leased lines.

U. S. Bureau of the Census, volumes of reports.

The committee is indebted to Mr. Joseph A. Arnold, Editor and Chief, Division of Publications, Department of Agriculture, for copies of the various publications of the department.

THE CONTENTS OF THE LIBRARY.

After transferring the mechanical pamphlets to the bound volumes and deducting the books withdrawn, the Library contains:

Volumes, bound and unbound	62,523
Pamphlets	47,045
Maps and charts	2,271
Photographs	1,336
Newspaper clippings	40,000
Manuscripts	34

BINDING.

Seven-hundred and thirty volumes were bound, 4 volumes were rebound, and 3 were repaired, an increase of 396 over the number of books bound during the preceding year. This increase must be credited to the Morris and Chemical Periodicals Binding Funds. The enormous number of pamphlets on mechanics have thus been made available for reference.

EVENING ATTENDANCE.

The Library was open on forty-two evenings during the year until 10 o'clock.

NOTES.

The additions to the Library during the past year have been greater than in any year since 1900.

This is due to the larger number of purchases and to the results of the more systematic attempts at procuring documents distributed without cost.

During the year two Library Bulletins were issued, the first giving the additions to the Library in the various departments during a period of about two years, and the second a list of the periodicals on file in the Library. These pamphlets will serve to make known to members and others

the material contained in the Library, and it is hoped that it will be possible to issue further bulletins of this character in the future.

As pointed out in the report for the preceding year, special funds are urgently needed for the binding of the great mass of books, periodicals, and pamphlets that has accumulated. It seems especially desirable that pamphlets on electrical and chemical subjects should be classified, bound, and catalogued in the same way as the Morris Fund provides for those on mechanics.

Respectfully submitted,

HARRY F. KELLER,
Chairman.

PHILADELPHIA, January 8, 1913.

REPORT OF THE COMMITTEE ON MUSEUMS.

(*Abstract.*)

To the President and Members of The Franklin Institute:

The Committee on Museums begs to report as follows:

The Franklin Institute possesses a large collection of models of great interest as well as of historical value. For years past many of these have been stored away out of sight in the cellar and elsewhere, covered with dust and the metal portions coated with rust. Through the liberal donations of a few members and the voluntary labors of Mr. Henry F. Colvin, the herculean task of collecting, cleaning, repairing, and classifying, so far as possible, this unique collection of models has been practically completed during the year, and a catalogue containing nearly three hundred separate entries (some covering numerous items) has been prepared by Mr. Bullock, Assistant to the Secretary. The Committee on Museums, having inspected the collection in its resuscitated condition, regard it as an exceedingly valuable asset, and desire to accord to the Secretary, Dr. R. B. Owens, the full credit due to him for having originated and carried to a successful conclusion this important and tedious work.

It is suggested that the catalogue of these models be printed in the Year-Book for 1913.

A brief reference to a few of these models and pieces of apparatus of historical interest will suffice to indicate the priceless value of the collection.

A very complete set of models of water-wheels made for the committee appointed by the Institute to investigate the efficiency of moving water as a motive power and used in conducting its water-wheel experiments. (Report of 1829.)

Original testing machine made for the committee appointed to investigate the strength of materials. This committee devised apparatus of various forms for the testing of metals, steam boilers, building materials, etc., 1832.

Model of canal boat with screw-propellers; also models of ice-boats and boats with feathering paddle-wheel blades.

Models of earliest forms of lattice girder bridges.

Sectional model of early beam engine with Watt parallel motion and condenser.

Model of locomotive engine, by George Stevenson, 1816.

Sectional model of side-lever engine.

Working models of early forms of stationary engines and locomotives.

Models by Eastwick, Harrison, Baldwin, and other inventors, of crank motions and various other portions of engines, such as cylinders, etc.

Model of Herman's mechanism for converting rectilinear into rotary motion.

Beam engine, by Henry Cartwright, model 1842.

Model of first World's Fair premium harrow.

Model of Bain's printing telegraph, 1844.

Various models and working apparatus of Morse and other inventors in the early history of telegraphy.

Model of Oliver Evans's "Oructor Amphibolis."

Original Yale lock, 1855.

Benjamin Franklin's original electrical machine and various other apparatus used by him.

In conclusion, it may be stated that all of the working models have been taken apart, cleaned, repaired by skilled mechanics, and all have been operated.

Some of these models are displayed in the Library and lecture-room; many others line the walls of the class-rooms, where they are at all times available for educational purposes.

Respectfully submitted,

A. E. OUTERBRIDGE, JR.,
Chairman.

PHILADELPHIA, January 8, 1913.

REPORT OF THE COMMITTEE ON MEETINGS.

To the President and Members of The Franklin Institute:

During the year ending September 30, 1912, nine stated meetings of the Institute were held under arrangements made by the Committee on Meetings, with the co-operation of the Secretary's office. At these the following subjects were presented:

September 20, 1911: Modern Uses and Applications of Radium. Dr. Hugo Lieber.

October 18, 1911: The Practical Application of Scientific Management to Railway Operation. Mr. Wilson E. Symons.

November 15, 1911: The Obstacles to the Progress of Meteorology. Prof. Cleveland Abbe.

December 20, 1911: Daylight. Dr. Edward L. Nichols.

January 17, 1912: Research Laboratory Notes. Dr. W. R. Whitney.

February 21, 1912: Recent Advances in the Art of Battleship Design. Naval Constructor D. W. Taylor, U. S. N.

March 20, 1912: How the Chemist Uses Electricity. Dr. Edgar F. Smith.

April 17, 1912: Recent Development of the Locomotive. Mr. George R. Henderson.

May 15, 1912: Fundamental Chemical Constants. Dr. E. W. Morley

Recent Developments in the Electrical Art. Prof. Elihu Thomson.

Metrology in Relation to Industrial Progress. Dr. S. W. Stratton.

The May meeting was made the occasion of the presentation of Elliott Cresson Medals to Dr. Alexander Graham Bell, Dr. Edward Williams Morley, Prof. Elihu Thomson, and Dr. S. W. Stratton, the last three being the speakers of that evening. The presentations were made on behalf of the Institute by Vice-President James Mapes Dodge, in the absence of the President, Dr. Walton Clark.

At this meeting, also, an amendment to the By-Laws, providing for the discontinuance of the June and September Stated Meetings, was considered and adopted in its final form.

Throughout the year the meetings were exceedingly well attended. The papers presented have practically all appeared in the Institute's JOURNAL.

Respectfully submitted,

JAMES S. ROGERS,
Chairman.

PHILADELPHIA, January 8, 1913.

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS.

To the President and Members of The Franklin Institute:

The Committee on Science and the Arts has the honor to submit the following account of its operation for the year ending September 30, 1912:

During the year there were held eleven Stated Meetings of the General Committee and twenty-three meetings of Sub-committees on Investigation.

There were eighteen cases pending before the committee in September, 1911, and, during the twelve months following, ten applications for investigation were accepted.

Twenty-four cases were closed during the year, leaving four cases pending, September 30, 1912.

In three of the cases considered, the award of the Elliott Cresson Medal was recommended and made. In two cases the award of the Edward Longstreth Medal of Merit was recommended and made. In four cases the award of the John Scott Legacy Medal and Premium was recommended; in two of these cases the John Scott Award was made by the City of Philadelphia; one case is now pending before the Philadelphia Board of City Trusts, and one recommendation is being advertised in the JOURNAL. Thirteen reports were made advisory and two cases were dismissed.

On the recommendation of the Special Committee on the awarding of the Elliott Cresson Medal in recognition of leading and directive work in science and the arts, nine awards were made.

On the recommendation of the Sub-committee on Literature, five Edward Longstreth Medals and one Howard N. Potts Medal for papers published in the JOURNAL were awarded.

A detailed list of the above awards is appended hereto.

No amendments to the Regulations of the Committee were considered.

The Chairman desires to express his sincere appreciation of the active and efficient co-operation of his fellow-members of the committee.

Respectfully submitted,

WILFRED LEWIS,
Chairman.

PHILADELPHIA, January 8, 1913.

APPENDIX.

Details of Awards.

THE ELLIOTT CRESSON MEDAL.

Johann Friedrich Adolph Von Baeyer, Ph.D., F.M.R.S., of Munich, Germany, in recognition of the many important results of his extended researches in organic chemistry and of his discovery of synthetic processes of great industrial value.

Alexander Graham Bell, Sc.D., Ph.D., LL.D., of Washington, D. C., in recognition of the value of his solution of the problem of the electrical transmission of articulate speech.

Sir William Crookes, D.Sc., LL.D., F.R.S., O.M., of London, Eng., in recognition of his important discoveries in inorganic and analytical chemistry and of his pioneer work on the discharge of electricity through gases.

Gray National Telautograph Company, of New York, N. Y., for their Telautograph.

Albert A. Michelson, Sc.D., Ph.D., LL.D., of Chicago, Ill., in recognition of his original and fruitful investigations in the field of physical optics.

Edward Williams Morley, Sc.D., Ph.D., LL.D., of West Hartford, Conn., in recognition of his important contributions to chemical science, and particularly of his accurate determinations of fundamental magnitudes.

Alfred Noble, C.E., LL.D., of New York, in recognition of his distinguished achievement in the field of civil engineering.

Sir Henry Enfield Roscoe, Ph.D., LL.D., D.C.L., F.R.S., of London, England, in recognition of his extended and important researches in the domains of inorganic, physical, and industrial chemistry.

Major George Owen Squier, Ph.D., of Washington, D. C., for his inventions in Multiplex Telephony.

Samuel Wesley Stratton, D.Eng., Sc.D., of Washington, D. C., in recognition of his distinguished and directive work in physical science and metrology, and its application in the arts and industries.

Elihu Thomson, Sc.D., Ph.D., of Swampscott, Mass., in recognition of

his leading and distinguished work in the industrial applications of electricity.

Walter V. Turner, of Wilmerding, Pa., for his Air Brake Inventions and Developments.

THE HOWARD N. POTTS MEDAL.

T. Lyttleton Lyon, Ph.D., and James A. Bizzell, Ph.D., for their paper on "The Relation of Certain Non-Leguminous Plants to the Nitrate Content of Soils" in the JOURNAL.

THE EDWARD LONGSTRETH MEDAL.

Professor Charles Baskerville, Ph.D., for his paper on "The Chemistry of Anæsthetics" in the JOURNAL.

Edwin M. Chance, for his paper on "The Examination and Physiological Action of Pathogenic Mine Atmospheres, with Considerations Governing the Use of Breathing Apparatus," in the JOURNAL.

Julian H. Granbery, for his Stadia Rod.

John Prue Karns, for his Tunnelling Machine.

Professor Edwin F. Northrup, Ph.D., for his paper on "An Experimental Study of Vortex Motions in Liquids" in the JOURNAL.

Oswald Schreiner, Ph.D., and Elbert C. Lathrop, A.B., for their paper on "The Distribution of Organic Constituents in Soils" in the JOURNAL.

Professor Carl C. Thomas, M.E., for his paper on "The Measurement of Gases" in the JOURNAL.

THE JOHN SCOTT LEGACY MEDAL AND PREMIUM.

Awarded by the City of Philadelphia on the recommendation of The Franklin Institute.

Sherard Cowper-Coles, of London, England, for his Process of Depositing Metals on Metallic Surfaces and the Product Thereof.

Louis W. Downes, of Providence, R. I., for his Process of and Machinery for Insulating Wire with Asbestos.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, January 8, 1913.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 8, 1913.

MR. GEO. R. HENDERSON *in the Chair.*

The following was accepted for examination:

No. 2523.—Ellis Adding Typewriter.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Aërial Navigation and Aëronautics.—A meeting of the section was held on Thursday evening, January 23, 1913, at 8 o'clock, in the Hall of the Institute. The meeting was called to order by Dr. Stradling, who, with a few preliminary remarks, introduced Dr. W. J. Humphreys, Director of the Mount Weather Observatory, U. S. Weather Bureau, and Professor of Meteorological Physics at the George Washington University.

Dr. Humphreys delivered an illustrated lecture on "Physics of the Atmosphere and Aviation."

He spoke of the means of exploring the atmosphere from mountains by means of kites and sounding balloons containing instruments, and, higher, by taking observations of shooting stars, auroral arcs, etc.

He considered the temperature and composition of the air at different levels, illustrating his remarks with interesting diagrams. The discovery of the isothermal—one of the most important discoveries of modern meteorology—and its explanation were described by him in detail.

By means of maps he explained the horizontal movement of the earth's atmosphere, directing attention especially to the "ocean highs."

He discussed wind structure, general circulation of air, and other subjects of vital interest to aëronauts. He also spoke of Simpson's modern theory of the electrical discharge in thunder-storms, giving a lucid description of this subject.

Throughout the lecture Dr. Humphreys held the close interest of his audience, and at the close of his remarks the thanks of the meeting were extended him.

Adjourned.

W. E. BULLOCK,
Acting Secretary.

Electrical Section.—A joint meeting of the section, and of the Philadelphia Section of the American Institute of Electrical Engineers, was held in the Hall of the Institute on Thursday evening, January 9, 1913, at 8 o'clock, Mr. W. C. L. Eglin and Mr. H. A. Hornor presiding jointly.

With a few introductory remarks Mr. Eglin introduced Mr. W. L. R. Emmet, Consulting Engineer and Engineer of Lighting Department, General Electric Company, Schenectady, N. Y., who spoke on "The Electric Propulsion of Ships."

Mr. Emmet gave some figures on the horsepower capacity of steam turbines now driving ships. He spoke of how these were for the most part applied to the fastest ships only. After mentioning work that had been done on gearing for speed reduction, he outlined the advantages of electricity for the same purpose.

He then showed lantern slides to illustrate his remarks. These slides included details of the electrical equipment (designed by him) on the U. S. collier *Jupiter*.

In the discussion which followed, Mr. Hornor, Mr. E. H. Rigg, and Mr. Bernard took part.

The thanks of the meeting were extended to the speaker.

Adjourned.

W. E. BULLOCK,
Acting Secretary.

MEMBERSHIP NOTES.

Elections to Membership.

(*Stated meeting of the Board of Managers, February 12, 1913.*)

RESIDENT.

MR. ALBERT B. BEADLE, 1328 Chestnut Street, Philadelphia, Pa.
MR. G. W. CURRAN, United Gas Improvement Company, Philadelphia, Pa.
MR. ERNEST HANDFIELD RIGG, 25 High Street, Woodbury, N. J.
MR. FRANK SILLIMAN, JR., 5987 Woodbine Avenue, Overbrook, Pa.

NON-RESIDENT.

DR. L. H. BAEKELAND, "Snug Rock," Harmony Park, Yonkers-on-Hudson, N. Y.
MR. C. A. COFFIN, General Electric Company, 30 Church Street, New York, N. Y.
MR. EDWIN P. GOTWALS, Lansdale, Pa.
MR. S. L. HAYES, 100 North Second Street, Millville, N. J.
PROF. JEFFERSON E. KERSHNER, Franklin and Marshall College, Lancaster, Pa.
MR. WILLIAM STANLEY, Great Barrington, Mass.

Changes of Address.

PROF. JEREMIAH D. BALTIMORE, Armstrong Technical High School, P Street, between First and Second Streets, N. W., Washington, D. C.
MR. GEORGE A. GRAVEMEYER, 122 South Thirteenth Street, Philadelphia, Pa.
DR. SAMUEL C. HOOKER, 82 Remsen Street, Brooklyn, N. Y.
MR. F. P. HOWE, Johnson City, Tenn.
MR. ERNEST JOHANSEN, 2022 Fairmount Avenue, Philadelphia, Pa.
DR. HARRY F. KELLER, 2313 Green Street, Philadelphia, Pa.
MR. TINIUS OLSEN, care of Rector Bertelsen, Roeskilde, Denmark.
MR. C. E. POSTLETHWAITE, P. O. Box 53, Pittsburgh, Pa.
MR. C. E. SARGENT, 2226 North Meridian Street, Indianapolis, Ind.
MR. C. C. TUTWILER, 1630 Real Estate Trust Building, Philadelphia, Pa.
E. D. WILLIAMS, ESQ., 309 South Fifteenth Street, Philadelphia, Pa.

NECROLOGY.

Sir John G. N. Alleyne, Chevin, Belper, England.

A. M. Schreuder was born in 1874. He was graduated from Cornell University as mechanical engineer in 1896. After leaving college, he was employed for some years by the Geo. M. Newhall Engineering Company, of Philadelphia. He then took up a position with the Tabor Manufacturing Company, also of Philadelphia. Early in 1908 Mr. Schreuder entered the

employ of The Philadelphia Textile Machinery Company, first devoting his energies to drawing-office work and advancing in a short time to the post of superintendent of the plant, having charge of both the Engineering Department and the shop management.

He died in Philadelphia on January 1, 1913.

LIBRARY NOTES.

Purchases.

APPELL, P.—Traité de mécanique rationnelle, vols. 1–3. 1909, 1911.
BAEYER, ADOLF VON.—Gesammelte Werke. 2 vols. 1905.
DALTON, J., and others.—The Expansion of Gases by Heat. [*c*1902.]
DROEGE, J. A.—Freight Terminals and Trains. 1912.
FARADAY, M.—The Discovery of Induced Electric Currents. [*c*1900.]
FARADAY, M., and others.—The Effects of a Magnetic Field on Radiation. [*c*1900.]
FARADAY, M., and others.—The Fundamental Laws of Electrolytic Conduction. [*c*1899.]
FRIEND, J. N.—The Corrosion of Iron and Steel. 1911.
GILBRETH, F. B.—Primer of Scientific Management. 1912.
GRANT, J.—The Chemistry of Breadmaking. 1912.
HARING, A.—Engineering Law, vol. i. 1910.
HENRY, J.—The Discovery of Induced Electric Currents. [*c*1900.]
HUYGENS, C.—Oeuvres completes, vols. i–xii. 1888–1910.
HUYGENS, C., and others.—The Wave Theory of Light. [*c*1900.]
KAYE, G. N. C., and T. H. LABY.—Tables of Physical and Chemical Constants. 1911.
KNESER, A.—Die Integralgleichungen und ihre Anwendungen in der mathematischen Physik. 1911.
MULLIKEN, S. P.—A Method for the Identification of Pure Organic Compounds, vols. i, iii. 1911.
NEWTON, I., and others.—The Laws of Gravitation. [*c*1900.]
PASTEUR, L., and others.—The Foundations of Stereochemistry. [*c*1901.]
PREVOST, P., and others.—The Laws of Radiation and Absorption. [*c*1901.]
SCHIDROWITZ, P.—Rubber. [1911.]
SENARMONT, H. DE, and others.—Oeuvres completes D'Augustin Fresnel, vols. i–iii. 1866–1870.
TRABERT, W.—Lehrbuch der kosmischen Physik. 1911.
WALKER, S. F.—Cold Storage, Heating and Ventilating on Board Ship. 1911.
WOODALL, H., and B. R. PARKINSON.—Distribution by Steel. 1911.
ZENKER, W.—Lehrbuch der Photochromie. 1900.
ZSIGMONDY, R.—Kolloidchemie. 1912.

Gifts.

West Virginia, Annual Report of the Department of Mines, 1911. Charleston, no date. (From Chief of the Department.)

Wisconsin Geological and Natural History Survey, "Sandstones of the Wisconsin Coast of Lake Superior." Madison, 1912. (From the Survey.)

Illinois Railroad and Warehouse Commission, Annual Reports, 1872, 1899-1904, 1906, 1910, 1911. Special Report, 1902–1906. Springfield, no date. (From the Commission.)

Southern Pacific Railroad Company, 19th–25th, 27th Annual Reports. New York, no date. (From the Company.)

American Society of Civil Engineers, Transactions, vol. 75, 1912. New York, 1912. (From the Society.)

Institution of Civil Engineers, Minutes and Proceedings, vol. 189. London, 1912. (From the Institution.)

Philadelphia, Academy of Natural Sciences, Journal, vol. 15. Philadelphia, 1912. (From the Academy.)

Manchester Steam-users' Association, Annual Report of the Boiler Explosion Act, 1882. Manchester, England, 1910-11. (From the Association.)

Mining Society of Nova Scotia, Journal, vol. 17, 1912–13. Halifax, 1912. (From the Society.)

Philadelphia, Bureau of Surveys, Annual Report, 1911. Philadelphia, 1912. (From the Bureau.)

Kentucky, Report of the Railroad Commission, 1904. Louisville, 1905. (From the Commission.)

Buchanan, N. Y., Experimental Researches on the Specific Gravity and the Displacement of Some Saline Solutions. London, 1912. (From the Author.)

Maine, Annual Report of the Railroad Commission for 1872, 1889, 1891, 1893, 1895, 1896, 1897, 1898, 1899, 1901, 1903, 1904, and 1905. Augusta, no date. (From the Commission.)

Louisiana, 1st, 2nd, 3rd, 4th, 12th, and 13th Annual Reports of the Railroad Commission. Baton Rouge, no date. (From the Commission.)

Hannover, Königliche technische Hochschule, Program, 1912–1913. Hannover, 1912. (From the School.)

Iowa, Annual Report of the Railroad Commissioners for the years 1899, 1901–1908. Des Moines, no date. (From the Commission.)

Kentucky, 31st and 32nd Annual Reports of the Railroad Commission, 1910–11. Frankfort, no date. (From the Commission.)

Florida, Fifteenth Annual Report of the Railroad Commission, 1912. Tallahassee, 1912. (From the Commission.)

Case School of Applied Science, Catalogue 1912–13. Cleveland, 1912. (From the School.)

Wesleyan University, Bulletin, vol. 6, No. 4, January, 1913. Middletown, Conn., 1913. (From the University.)

National Association of Cotton Manufacturers, Transactions, No. 91. Boston, 1912. (From the Association.)

New Zealand, Papers and Reports Relating to Minerals and Mining, 1912. Wellington, 1912. (From the Department of Mines.)

U. S. Army, Index Catalogue of the Library of the Surgeon-General's Office, Second Series, vol. 17. Washington, 1912. (From the Library.)

Great Britain, Board of Trade (Labor Department) Report on Strikes and Lock-outs, 1911. London, 1912. (From the Department.)

Ontario Department of Agriculture, Report of the Women's Institutes, 1912, Part 1. Toronto, 1912. (From the Department.)

Cuba, Instituto De 2ª Ensenanza, Memoria Anual 1909 á 1910. De La Habana, 1912. (From the Instituto.)

Canada, Minister of Public Works, Report 1912, vol. 1. Ottawa, 1912. (From the Minister.)

Vermont Historical Society, Proceedings 1909–10. Montpelier, no date. (From the Society.)

Massachusetts, State Board of Health, Annual Report 1911. Boston, 1912. (From the Board.)

"George von Reichenbach," by Walther von Dyck. München, 1912. (From the German Museum of Munich.)

Institution of Naval Architects, Transactions, vol. 54. London, 1912. (From the Institution.)

Institution of Naval Architects, Index to Transactions, vols, 47 to 54. London, 1912. (From the Institution.)

PUBLICATIONS RECEIVED.

Fatty Foods, their Practical Examination. A handy book for the use of analytical and technical chemists, by E. Richards Bolton, F.C.S., and Cecil Revis. 371 pages, illustrations, plates, 12mo. Philadelphia, P. Blakiston's Son & Co., 1913. Price, in cloth, $3.50.

Methods of Measuring Electrical Resistance, by Edwin F. Northrup, Ph.D. 389 pages, illustrations, 8vo. New York, McGraw-Hill Book Company, 1912. Price, in cloth, $4.00.

Michigan State Board of Health, Thirty-ninth annual report of the Secretary for the fiscal year ending June 30, 1911. 118 pages, 8vo. Lansing, State Printers, 1912.

North Carolina Geological and Economic Survey: Economic Paper, No. 29, Report of the Fisheries Convention held at Newbern, N. C., December 13, 1911. Compiled by Joseph Hyde Pratt, State Geologist. 302 pages, 8vo. Economic Paper, No. 30, Proceedings of the Annual Convention of the North Carolina Good Roads Association, held at Charlotte, N. C., August 1 and 2, 1912, in co-operation with the North Carolina Geological and Economic Survey. Compiled by Joseph Hyde Pratt, State Geologist, and Miss H. M. Berry, Secretary. 110 pages, 8vo. Raleigh, State Printers, 1912.

Canada Department of Mines, Mines Branch: A General Summary of the Mineral Production of Canada during the Calendar Year 1911. John McLeish, B.A., Chief of the Division of Mineral Resources and Statistics. 38 pages, 8vo. The Production of Coal and Coke in Canada during the Calendar Year 1911. John McLeish, B.A., Chief of the Division of Mineral Resources and Statistics. 35 pages, 8vo. Ottawa, Government Printing Bureau, 1912.

Philippine Islands, Bureau of Science, The Mineral Resources of the

Philippine Islands for the year 1911. Issued by the Division of Mines, Bureau of Science, Warren D. Smith, Chief. 99 pages, illustrations, maps, plates, 4to. Manila, Bureau of Printing, 1912.

U. S. Bureau of Standards, Circular No. 39, Specifications for and Measurement of Standard Sieves. 14 pages, 8vo. Washington, Government Printing Office, 1912.

Königliches Materialprüfungsamt der Technischen Hochschule zu Berlin, Jahresbericht 1911. Aufgaben, Gliederung des Betriebes und Grundsätze für die Geschäftsführung. 2 pamphlets, 4to. Berlin, Julius Springer, 1912.

Pennsylvania Chestnut Tree Blight Commission, Bulletin No. 2, Treatment of Ornamental Chestnut Trees Affected with the Blight Disease. 7 pages, illustrations, 8vo. Harrisburg, State Printer, 1912.

U. S. Department of Agriculture, Forest Service: Bulletin 104, Principles of Drying Lumber at Atmospheric Pressure and Humidity Diagram, by Harry D. Tiemann, in charge Timber Physics. 19 pages, tables, 8vo. Circular 205, Forest Fire Protection under the Weeks Law in Co-operation with States, by J. Girvin Peters, Chief of States Co-operation. 15 pages, maps, 8vo. Report of the Forester for 1912, by Henry S. Graves. (From annual reports of the Department of Agriculture.) 95 pages, 8vo. Washington, Government Printing Office, 1912.

U. S. Bureau of Mines: Miners' Circular 10, Mine Fires and how to Fight Them, by James W. Paul. 14 pages, 8vo. Technical Paper 29, Training with Mine-Rescue Breathing Apparatus, by James W. Paul. 16 pages, 8vo. Washington, Government Printing Office, 1912.

University of Colorado Bulletin, Municipal Water Supplies of Colorado, by Clement C. Williams, C. E., Assistant Professor of Civil Engineering. 56 pages, illustrations, map, 8vo. Boulder, Col., University, 1912.

Royal Institution of Great Britain, Weekly evening meeting, Friday, May 17, 1912, High Frequency Currents, by W. Duddell, Esq. 23 pages, illustrations, 8vo. Friday, May 31, 1912, Icebergs and their Location in Navigation, by Professor Howard T. Barnes. 20 pages, illustrations, 8vo. London, Institution.

U. S. Geological Survey, Chart showing mineral products of the United States, calendar years 1902 to 1911, size 24 x 32 inches. Washington, 1912.

U. S. Commissioner of Lighthouses, Annual report for the fiscal year ended June 30, 1912. 108 pages, 8vo. Washington, Government Printing Office, 1913.

BOOK NOTICES.

THE METALLOGRAPHY OF IRON AND STEEL. By Albert Sauveur, Professor of Metallurgy and Metallography in Harvard University. One volume quarto, edition 1, University Press, Cambridge, Mass., 1912, cloth, $6.

This really splendid work gives to the metallurgists the "last word" regarding a comparatively new science—that of Micro-Metallography—the birth of which was very nearly contemporaneous with the coming of the twentieth century.

Twenty years ago a few pioneers had already paved the way for enthusiastic followers, like Professor Sauveur, by their original investigations with the microscope, assisted by photography, into the molecular structure of metals, revealing complicated combinations hitherto unknown. Chemical analysis had long before that time made us acquainted with the component elements of alloys; we had attained the *ultima thule* of knowledge of the chemical composition of metals and alloys, but until the powerful eye of the microscope was trained upon the polished and etched surfaces of such metals we were unable to explain the vast differences in physical properties of pure metals and their alloys caused by differences of heat treatment, or by minute variations in compositions too small for detection by ordinary chemical analysis, or by still other more or less mysterious causes.

For several years the whole subject of micro-metallography was regarded by practical men as an interesting one solely from an academic or theoretical point of view, but, gradually at first, then more and more rapidly, came a realization of the immense importance of micro-metallography in industrial establishments engaged in manufacturing and fashioning metals into various useful forms.

Professor Sauveur was a pioneer in this latter development, and the writer regards the now somewhat scarce volumes of "The Iron and Steel Metallurgist and Metallographist," edited by Professor Sauveur for several years, more than a decade ago, as a remarkable monument to his energy and foresight, which has now found its full fruition in the classic book under review, which will doubtless be considered by experts as entitled to this encomium.

The book is divided into twenty-four chapters, called "Lessons." Each one is a complete text-book in itself upon a special branch of the main subject, copiously illustrated with diagrams and photo-micrographs. There is an interesting "Introduction" clearly showing the industrial importance of Metallography; also a full description of apparatus for the metallographic laboratory, and various appendices, together with complete "Index" and "Table of Contents."

With such a wealth of subjects to choose from it is somewhat difficult to specify any one as having particular importance, but attention may be called to the very clear exposition of the meaning of "The Phase Rule" not always understood.

The following is a list of the "lessons" or chapters:

(1) Pure Metals.
(2) Pure Iron.
(3) Wrought Iron.
(4) Low Carbon Steel.
(5) Medium High and High Carbon Steel.
(6) Impurities in Steel.
(7) Thermal Critical Points of Iron and Steel. (Occurrence.)
(8) Thermal Critical Points of Iron and Steel. (Causes.)
(9) Thermal Critical Points of Iron and Steel. (Effects.)
(10) Cast Steel.
(11) Mechanical Treatment of Steel.

(12) Annealing of Steel.
(13) Hardening of Steel.
(14) Tempering of Hardened Steel.
(15) Theories of Hardening of Steel.
(16) Cementation and Case Hardening of Steel.
(17) Special Steels. (General Considerations.)
(18) Special Steels. (Constitution, Properties, and Treatment and Uses of Most Important Types.)
(19) Cast Iron.
(20) Impurities in Cast Iron.
(21) Malleable Cast Iron.
(22) Constitution of Metallic Alloys.
(23) Equilibrium Diagram of Iron-Carbon Alloys.
(24) The Phase Rule.
Appendix 1, Manipulations and Apparatus.
Appendix 2, Nomenclature of the Microscopic Constituents.
Errata.

The reviewer confesses that after close inspection he has been unable to detect any errors other than those few that have been already noted on a page marked "Errata," showing very careful editing.

Finally, it may be said that the typography, paper, drawing of the numerous diagrams, woodcuts of apparatus, and photographic half-tone illustrations are unusually good.

The author is to be congratulated on the production of a book worthy of his reputation, one which will prove of permanent benefit to metallurgists as well as manufacturers of steel and iron and to workers in metals generally.

A. E. OUTERBRIDGE, JR.

PENROSE'S PICTORIAL ANNUAL. The Process Year Book for 1912-13, vol. 18, edited by William Gamble, F.R.P.S. London, A. W. Penrose and Company, Ltd. 268 pages, illustrations, plates. American agents, Tennant & Ward, New York City. Price, $3.

The eighteenth volume of this interesting annual, recently issued, contains matter of value to every one connected with the graphic arts. Specimens of the numerous processes for producing half-tone and color prints form an important feature of the volume. There are many monochrome, two-color, three-color, and four-color plates and numerous other examples of printing. The contributors include names of process workers known throughout the world, and their articles deal with the many subjects connected with the reproductive processes. An excellent portrait of Sir W. de W. Abney forms an interesting feature of the work.

CURRENT TOPICS.

Sulphuric Acid Industry in the United States. U. WEDGE. (*Eighth Int. Cong. Appl. Chem., Sect. II, Orig. Comm.*, ii, 241.)—The annual consumption of sulphuric acid in the United States is approximately, when reckoned as at 50° Be., for the manufacture of phosphatic fertilizer, 2,400,000 tons; for refining petroleum products, 300,000 tons, or, taking into account its repeated use, acid equivalent to 500,000 tons is actually employed; for use in the iron and steel and coke industry, 200,000 tons; for the manufacture of nitrocellulose, nitroglycerin, celluloid, etc., 150,000 tons; and for other purposes, 200,000 tons. In 1911, 2,665,000 tons of this acid were made from pyrites; 275,000 tons from copper sulphide ores, smelted in blast furnaces; 285,000 tons from zinc sulphide ores, and 25,000 tons from brimstone. It is found most economical to erect combined sulphuric acid and fertilizer works adjacent to the agricultural districts where the fertilizer is consumed; these works are especially numerous in the Southern States where cotton is grown. Acid works are similarly located near oil refineries, and there is said to be a growing tendency for steel companies to make their own acid. Contact processes have been installed wherever nitrocellulose and similar products are manufactured, and about 10 per cent. of the total production of acid is made by one or other of the contact processes. The practice of nodulizing cinder from pyrites burners is said to have become general in all localities where there is a market for the nodulized cinder as iron ore.

"Iron Coke." A. P. LIDOFF. (*Eighth Int. Cong. Appl. Chem.*, 1912, *Sect. III, a, Orig. Comm.*, iii, 11.)—By passing the dust from blast furnaces repeatedly through magnetic separators a product is obtained rich in ferric oxide. One part of this dust is mixed with three parts of caking coal slack and heated to a high temperature under pressure. A porous coke is obtained, containing metallic iron regularly distributed through it. This material might be used for electrodes, or as a filtering medium, or for decolorizing solutions.

Waste and Losses in the Production of Minerals in the United States. ANON. (*Oil, Paint, and Drug Reporter*, Sept. 2, 1912.)—The Director of the United States Bureau of Mines has issued a statement describing some of the losses sustained in the yearly production of minerals in the United States. During the last year,

in producing a billion tons of coal, a quarter of a billion tons were wasted or left underground; and a quantity of natural gas, larger than the total output of artificial gas during the same period in all the towns and cities of the United States, was allowed to escape. Many valuable mineral deposits are lying idle while the products are being imported from other countries. In mining coal in the United States, probably one-third of the bituminous coal and one-half of the anthracite are left in the mine. Fully 80,000,000 tons of anthracite are now being left behind in the mine each year, and it is estimated that since mining began in this country fully 2,000,000,000 tons of anthracite and 3,000,000,000 tons of bituminous coal have been left in the ground under conditions which make future recovery highly improbable. Probably not more than 11 per cent. of the energy in coal is being effectively utilized. The losses in making coke by the old-fashioned process wasted $40,000,000 in the United States last year. These coke ovens, without taking into account the value of the by-products that were possible, wasted more than 1,000,000 horsepower in the year. Almost inestimable losses of sulphur, arsenic, and bismuth are now occurring in the flue dusts and flue gases. In proportion to output, the losses of zinc are probably greater than those of any other metal, and are especially important because there is almost no recovery of zinc from manufactured products and almost no conservation of zinc by accumulation. Besides these losses in the mining and concentration of zinc ores, there are incalculable losses which undoubtedly exceed the total value of the zinc mined, in slags and waste products from other processes. In combined, but unfortunately relatively insoluble, form there are unlimited supplies of potash in the United States, but economical methods of extraction are not known. The waste of nitrogen is almost inconceivable. Although last year over 406,000,000 tons of bituminous coal were produced, only $3,800,000 of the $160,000,000 worth of recoverable nitrogen in the coal was obtained. Of 63,000,000 tons of coal converted into coke in 1910, containing $22,000,000 worth of recoverable nitrogen, only about one-sixth was treated in ovens or retorts which could make that recovery possible. The waste and the utilization of sulphur are both enormous, and depend largely on local conditions. The United States is producing annually about 3,000,000 tons of sulphuric acid, approximately one-half of which is used in the manufacture of fertilizers. The total amount of sulphur dioxide discharged into the air in the United States would unquestionably suffice to make more than 8,000,000 tons of sulphuric acid annually.

Influence of Phosphorus, Manganese, and Tin on the Physical Properties of Copper. E. MÜNKER. (*Metallurgie*, ix, 185.)—In investigating the effect of phosphorus, up to 1.06 per cent.;

of manganese, up to 1.49 per cent., and of tin, up to 1.46 per cent., on the tenacity, hardness, electrical conductivity, and density of copper in various conditions, depending upon the mechanical and thermal treatments to which the alloys were subjected, the following conclusions were reached: All three elements increase the tenacity and hardness, but decrease the elongation, electrical conductivity, and specific gravity. Annealing affects all the alloys in the same way. Tenacity and hardness are diminished, the elongation is increased, while the density and conductivity are barely affected. This paper is illustrated by 16 photomicrographs, showing the effects of annealing on the structure of the alloys.

Detection of Carbon Monoxide in Air. R. NOWICKI. (*Elektrochem. Zeitschr.*, xix, 35.)—A pocket apparatus for detecting carbon monoxide is made by C. Glatzel, Mährisch Ostrau, Austria. It consists of a U tube, fitted with two stop-cocks, and held in a wider glass tube. By alternately compressing and relaxing a rubber ball the glass tube is charged with the air to be examined. If the air contains carbon monoxide, a strip of paper moistened with palladious chloride turns brown; and if the content of carbon monoxide is more than 0.1 per cent., this occurs within one minute.

Vanadium in Pig Iron. P. W. SHIMER. (*Trans. Amer. Inst. Min. Eng.*, 1912, 883.)—The iron ore mixtures smelted in the Lehigh Valley district contain varying amounts of New Jersey magnetite in which vanadium and titanium generally occur to the extent of 0.05 and 0.60 per cent. respectively. The pig iron produced, which generally contains 0.02 to 0.05 per cent. of vanadium and 0.10 to 0.20 of titanium, is fine grained and soft and possesses unusual strength. These qualities are ascribed to the vanadium, although probably titanium has a similar action. It was found that practically the whole of the vanadium and titanium contained in such pig iron is insoluble in dilute hydrochloric acid, indicating that these elements are present in combined form, probably as carbides; even in a steel containing 0.143 per cent. of vanadium, about one-half of it was found to be present in an unalloyed state. The beneficial effect of vanadium and titanium upon pig iron is probably due to the elimination of nitrogen and oxygen, and, furthermore, they modify the structure of the metal by separating out first in finely-divided condition (probably as carbides) during the solidification, and thus provide uniformly-distributed nuclei around which the iron rapidly crystallizes. Various iron ores from other districts were found to contain from 0.006 to 0.023 per cent. of vanadium, and it is stated that it sometimes occurs in limestone and in the ash of coke. By remelting in a cupola, the vanadium content of a charge of cast iron was reduced from 0.0313 to 0.027 per cent.

Vanadium Deposits in Colorado, Utah, and New Mexico. F. L. HESS. (*U. S. Geol. Survey,* Bull. 530–K.)—Vanadium occurs at Placerville, Col., disseminated in a dull green sandstone along seams or in veins containing roscoelite, quartz, and pyrite. Carnotite appears as a lining on the joint surfaces. A sandstone of lighter green color owed its color to mariposite, a chromium mica. Near Green River, Utah, carnotite ore is reported to have been shipped containing 2.2 per cent. uranium oxide and 3.8 vanadium oxide. Vanadinite has been found at Los Caballos, New Mexico.

Bronson Resistances. FR. HAUSER. (*Physik. Zeit.,* xii, 785.)—The spherical form appears to be most satisfactory for general work. By making the radius of the sphere about 1.25 times the range of the α rays emitted by the ionizing substance, the current is then proportional to the applied potential; *i.e.,* Ohm's law holds good.

A Powerful Lamp for Ultra-violet Rays and its Use in the Sterilization of Large Quantities of Water. V. HENRI, A. HEILBRONNER, and M. DE RECKLINGHAUSEN. (*Compt. Rend.,* clv, 852.)—The lamp consists of a quartz U-tube the sides of which nearly touch one another; the diameter of the tube is 14 mm., and the length of the arms 160 mm. The two mercury electrodes are side by side. The lamp requires a current of 500 volts, with a difference of potential between the electrodes of 375 to 390 volts, with an intensity of 3 ampères. The illuminating power perpendicular to the axis is 8000 candles. Chemical reactions induced by ultra-violet rays are very greatly accelerated by the use of the new lamp. Germicidal action on *Bacillus coli* is 60 times as rapid as with a 110-volt lamp. For sterilizing large quantities of water, the lamp is placed in a cylinder of transparent quartz, which is placed in the centre of the tank through which the water passes, and the water is forced to circulate round the cylinder by a series of baffles. Thus the lamp burns as in air, and the rays are completely utilized. An installation of 8 lamps has worked 1200 hours without change, the strength of the rays being tested each day by the rapidity of the blackening of silver citrate paper exposed to them.

Petroleum Discovered in Siam. ANON. (*Oil, Paint, and Drug Reporter,* Oct. 28, 1912.)—New discoveries of petroleum have been made in Siam, located above the Tachin River, in the district north of Korat. Some villagers in Laos discovered the oil about five years ago, and draw it by means of long bamboos, reaching a depth of 60 feet. This crude oil smokes heavily when burned. It is, however, practically inaccessible, being about 200 miles from the nearest railway station.

Italian Electro-Chemical Industry in 1911. ANON. (*Chem. Trade J.*, Nov. 2, 1912.)—The official statistics for 1911, published by the Italian Ministry of Industry and Commerce, show that the production of calcium carbide was less than that of the previous year, which in turn was less than that of 1909; thus it was the lowest production of late years. Cyanamide, too, remained at a low figure, 4470 metric tons, as compared with 3715 in 1910. In the district of Rome the decrease in the production of carbide was 11,000 tons, as compared with 1910, and only four works were in operation, instead of six in the previous year. Good results, however, were obtained from the sales by the Italian General Company for the carbide trade, production being limited to the needs of the markets, which are steadily developing, owing to acetylene lighting and the manufacture of cyanamide and ammonium sulphate. At Collèstate all the plant has been installed for the manufacture of cyanamide. This installation comprises three jaw crushers; three ball mills; a Linde machine for the liquefaction of air and production of nitrogen; 106 retorts, each with a capacity of 1500 kilos, to transform 3251 tons of carbide into 4000 tons of granular cyanamide, a part of which is used for the manufacture of ammonium sulphate by treatment with steam at 190° C. in three autoclaves, and the subsequent combination of the sulphuric acid with the ammonia. In the district of Bologna the Ascoli Piceno Works began normal work in 1911 and manufactured 8000 tons of carbide with three electric furnaces utilizing 6000 horsepower. Porto Ferraio, in the Florence district, has recommenced the manufacture of carbide with Stassano furnaces. The Societa Ferriere, in Milan, has reduced manufacture from 4000 tons to 2633 tons.

Recovery of Metallic Iridium. ANON. (*Eng. and Mining J.*, xciv, 802.)—Metallic iridium is made from the iridium powder left in the wet process of platinum refining. This powder cannot be melted alone, but is converted into iridium phosphide by strongly heating with stick phosphorus in a silica crucible. The iridium phosphide is then heated with lime to remove the phosphorus, leaving a brittle white mass of iridium, which cannot be filed or cut, but is broken into the small pieces necessary for pen points, which are ground into shape by carborundum. These pieces of iridium are said to be about as hard as the ruby.

New Form of Emanation Electroscope. W. HAMMER. (*Deutsch. Phys. Gesell. Verh.*, xiv, 13.)—The principle of the apparatus is that radium emanation is removed from any solution containing radium by simply shaking it. A rod leading from the vessel can be connected with any kind of electroscope and the ionization current measured. This instrument avoids any loss of emanation by transference.

Cementation of Iron by Gases. F. KUREK. (*Stahl u. Eisen*, xxxii, 1780.)—Experiments on cementation were made, using carbon monoxide, methane, and illuminating gas, and the same gases with an admixture of ammonia. The results showed that cementation with carbon monoxide at ordinary pressures cannot be used advantageously, the carburization being too slow, and that the addition of ammonia is not favorable to the formation of carbide. Methane at 800° C. had no action, but at 900° C. and 1000° C. caused considerable carburization. Illuminating gas yielded markedly higher carbon in the outer layers than methane. At 800° C. and 900° C. carburization did not penetrate far into the iron, but at 1000 C. carbide was formed throughout. Admixture with ammonia was no advantage.

Influence of Carbon on the Corrodibility of Iron. C. CHAPPELL. (*Iron and Steel Inst. Journ.*, lxxxv, 270.)—This article gives the results of investigations as to the nature and extent of the influence of increasing percentages of carbon on the corrodibility of iron. Suitable bars of practically pure carbon steels were subjected to typical heat treatments, and their relative corrodibilities determined in each of the various conditions produced by such treatment. The polished specimens were examined after 91 days' immersion in sea-water, and were then reimmersed for a further period of 75 days. The following are the chief conclusions arrived at as the result of this work: (1) *Influence of carbon on corrodibility:* (*a*) In rolled, normalized, and annealed sheets, the corrodibility rises with carbon-content to a maximum at saturation point, 0.89 per cent. carbon, and falls with any increase of carbon beyond this point. (*b*) In quenched and tempered steels a continuous rise of corrodibility occurs with the increase of carbon up to 0.27 per cent., no maximum corrodibility at saturation point being found in these steels. (2) *Influence of treatment on corrodibility:* Quenching increases the corrodibility to a maximum, annealing tends to reduce it to a minimum; normalizing gives intermediate values. The influence of tempering varies with the tempering temperature. (3) *Factors determining corrodibility:* The electromotive forces between the ferrite and the pearlite, and between the components of the pearlite itself, are the principal factors determining the corrodibility of unsaturated pearlitic steels above 0.4 per cent. carbon. In mild structural steels this galvanic action is accompanied by a further galvanic action between the ferrite crystals themselves, due to differences in their orientation. The state of division of the pearlite and the presence of internal stresses in the steel may exert some influence on the foregoing factors. (4) *Influence of time on corrodibility:* The influence of time on the rate of corrosion varies with different steels. In a low-carbon steel it is found to be practically directly proportional to the length of

time of immersion. (5) The influence of corrosion on the resistance offered by a low-carbon steel to alternating stress is not appreciable within a period of 5 months' immersion. (6) Three per cent. of tungsten has no effect on the corrodibility of carbon steels. (7) Decarbonization increases the resistance to corrosion. (8) The two oxides, ferrous oxide and the ferro-ferric (magnetic) oxide, both exert a microscopical pitting effect on steel when in contact with it in sea-water.

Production of Electric Steel. ANON. (*Mining and Eng. World,* Nov. 12, 1912.)—The production of steel in electric furnaces during the last three years was, in tons:

	1909	1910	1911
Germany	17,773	36,188	66,654
United States	13,762	52,141	29,105
Austria-Hungary ..	9,046	20,028	22,867
France	6,456	11,759	13,850
	47,037	120,116	132,476

The United Kingdom had hardly commenced to produce for the general market. The predominating lead of Germany and the drop in the electric steel production of the United States are notable features of last year's figures. Activity in France lies more in the field of ferro-alloys. Of these France made altogether, in 1904, 34,200 tons, which was increased to 60,200 tons by 1910. The ferro-alloys made in electric furnaces were respectively 5756 tons and 23,800 tons. The electrically-produced alloys in 1909 amounted to 14,900 tons, and varied little in the years 1906 to 1909.

Composition of Thorianite. M. KOBAYASHI. (*Science Reports, Tôhoku Imp. Univ., Sendai, Japan,* i, 201.)—An examination of specimens of thorianite indicated that there are two varieties of the mineral, one containing about 78 per cent. of thorium oxide and 15 per cent. of uranium oxide, a molecular ratio of thorium oxide to uranium oxide = 6 : 1; and the other about 60 per cent. of thorium oxide and 33 per cent. of uranium oxide, a molecular ratio of thorium oxide to uranium oxide = 2 : 1. Different results hitherto obtained may be explained by the assumption that mixtures of the two varieties in varying proportions were analyzed. Dunstan and Jones described a thorianite from Ceylon rich in uranium, and expressed the view that in thorianites the thorium and uranium oxides are not in chemical combination, but are present as isomorphous mixtures. Against this view the author points out that the simple molecular ratio of the two oxides can hardly be a coincidence; and that, whilst ignited thorium oxide is nearly insoluble in nitric acid, thorianite dissolves fairly readily, even after ignition.

Copper Alloy Resistant to Acids. ROBERT GRIMSHAW. (*The Metal Industry*, x, 12, 498.)—An alloy of 40 per cent. cobalt and 60 per cent. tin is especially resistant to acids, even to concentrated nitric acid and to this acid mixed with chlorides. It is, however, so brittle as to be unworkable, and is therefore practically worthless. If, however, this alloy is dissolved in copper, so as to form a new alloy of 80 to 95 per cent. copper and 20 to 5 per cent. of the cobalt and tin, a series of alloys is obtained which may be filed, bored, turned, forged, etc., and also have a high degree of chemical resistance. It has been found preferable to make the cobalt-tin alloy first and then dissolve that in the copper.

Opacity to X-Rays. L. G. DROIT. (*Comptes Rendus*, clv, 706.)—Silk fabrics were loaded with lead phosphostannate, by the ordinary processes of mordanting with metallic salts. One such fabric weighed 266 Gm. per square metre, and 68 per cent. of its weight consisted of mineral matter (lead oxide 34, stannic oxide 24, phosphoric anhydride 8, lime and alkali 2). Two layers of this were found to be so slightly permeable by "soft" discharges, and six layers by medium or ordinary discharges, as to form an efficient protection against the injurious effect of X-rays on the skin. At the same time the covering with six layers was sufficiently flexible for work. This fabric had an opacity equivalent to a sheet of copper 0.044 mm. thick.

Melting Points of Firebricks and Clays. ANON. (*Brass World*, viii, 12, 432.)—The Bureau of Standards recently determined the melting points of firebricks in an accurate way. The results are interesting as indicating the commercial value, with regard to their heat-resisting properties, of the various kinds of firebricks. The results obtained were:

Fire clay brick	1555° to 1725° C.
Bauxite brick	1565° to 1785° C.
Silica brick	1700° to 1705° C.
Chromite brick	2050° C.
Magnesia brick	2165° C.
Kaolin	1735° to 1740° C.
Bauxite	1820° C.
Bauxite clay	1705° C.
Chromite	2180° C.
Pure alumina	2010° C.
Pure silica	1750° C.
Carborundum	2700° C.

The value of 1750° given for silica is not the true melting point, but represents the temperature at which the silica distinctly flows.

The Second Law of Thermodynamics.—C. P. STEINMETZ. (*Engineer*, cxiv, p. 103. *From the "General Electric Review."*)—The second law of thermodynamics is discussed and several popular misconceptions with regard to it are referred to. It is concluded that the second law of thermodynamics is not a universal law of nature, but applies only within the limited range of thermodynamic engines from which it has been derived. It does not apply to the universe as a whole; and the conclusion sometimes deduced from it, that the universe must finally come to a standstill, is not justified. (This is in accordance with Nernst's own statement, that the laws of Physics, in general, are only true within certain limits.—ABSTRACTOR.)

Influence of Pouring Temperature on Aluminum Alloys. H: W. GILLETTE. (*Eighth Int. Congr. Appl. Chem., Sect. II, Orig. Comm.*, ii, 105.)—Comparative experiments on the tensile strength of castings of aluminum and a series of aluminum alloys were made with a view to ascertain the effect of the pouring temperature on this property; it was shown that, on the average, bars poured hot, at 815° to 871° C., are nearly 20 per cent. weaker than bars of the same material poured cold, at 649° to 704.5° C., owing to the slower crystallization in the former case, and it is suggested that in all tests of cast aluminum alloys the pouring temperature should be recorded as well as the dimensions of the test piece and the composition of the mould. These also affect the rate of crystallization, *i.e.*, the fineness of grain, of the metal. The addition of small amounts of manganese, titanium, iron, or antimony to the alloy containing 8 per cent. of copper (that most used for casting) was found to increase the strength when poured hot, but at the same time to cause brittleness and to decrease the resistance to impact. It is stated that at the most modern foundries aluminum castings are now poured at the lowest temperature at which the mould will fill, without forming blow-holes. It was found that platinum thermo-couples are unsuitable for taking the pouring temperature, owing to "lag"; and the use of base metal couples or "fire rods, of the welded end, rod, and tube type," are recommended.

Absorption of Ultra-violet Vibrations by Radioactive Elements of their Degradation Products. N. D. ZELINSKY. (*Acad. Sci. St. Petersbourg Bull.*, vi, 465.)—The author's measurements of the absorption spectra of radioactive and other substances show that the activity of elements obtaining their energy from some unknown source, probably from the internal, potential energy of the atom, is exhibited in the absorption of ultra-violet light, both by the active materials themselves and by their emanations. This new method of detecting the presence of radioactive substances increases the methods now available to five.

Improvement in Yield of Open-hearth Steel. F. W. PAUL. (*Iron and Steel Inst.*, Sept., 1912.)—A review is given of the ordinary practice of open-hearth steel manufacture with special reference to the yield obtained, after which a new method of charging and of eliminating silicon is proposed. *Charging.*—After the pig iron is all charged and the silicon sufficiently removed to permit the metal to be superheated without loss, the steel scrap is charged in such quantities as to allow the bath to remain molten. *Melting.*—The pig iron and scrap floating in a molten bath of metal with a protective coating of slag is thus protected from the oxidizing atmosphere of the furnace, and less waste ensues and the yield is increased. By this means the melting stage and the silicon elimination stage are merged into one, and the silicon is removed during a period of six hours or more with the metal at a low temperature, and therefore the scouring action on the "banks" is considerably diminished and the temperature of the iron and the content of oxide of iron in the slag can be controlled so that the reaction takes places without the emission of brown smoke. The following important features of these proposals have been practically confirmed in a 70-ton furnace: (1) A very decided increase in yield. (2) The practicability of so superheating the de-siliconized metal as to permit the addition of cold steel scrap without causing partial solidification of the charge. (3) Charges of all-pig iron can be worked with considerable increase in yield compared with charges of pig iron and scrap. (4) The brickwork of the furnace is not subjected to such extreme fluctuations of temperature. (5) During the melting stage the level of the metal in the furnace is continually altering, and thus the scouring action on the thin top part of the "banks" avoided, and there is less loss of time for repairs and less risk of "breakouts." (6) The prevention of oxide of iron fumes will probably lengthen the life of the chambers.

Combination of the Contact Process with the Lead Chamber or Tower Systems in the Manufacture of Sulphuric Acid. W. WILKE. (*Eighth Int. Congr. Appl. Chem.*, Sect. II, *Orig. Comm.*, ii, 249.)—The gases from the pyrites burners are conducted into an iron oxide contact shaft, in which the sulphurous gases undergo conversion into sulphur trioxide to the extent of about 30 per cent., and thence are driven by a fan through the Glover tower to the chambers. The combination of the two processes is said to increase the capacity of the chamber plant by at least 30 per cent., and to allow of more uniform working, besides effecting a saving of 30 per cent. in the nitre consumed. It was found that the total production of the chamber system could easily be concentrated to 60° Be. or higher in the Glover tower, and the acid produced was colorless. The iron oxide also eliminates 95 per cent. of the arsenic carried by the gases, and prevents dust from reaching the chambers.

Tartaric Acid and Cream of Tartar. ANON. (*Oil, Paint, and Drug Reporter,* Oct. 14, 1912.)—The United States Treasury Department has issued the following instructions to collectors of customs at ports where laboratories of the Department of Agriculture are established: "That refined tartaric acid and cream of tartar containing lead in excess of 20 milligrammes per kilogram shall be held as adulterated, under section 7, paragraph 5, under Foods, in that they contain an added poisonous and deleterious ingredient which may render the product injurious to health."

American Petroleum. ANON. (*Eng.,* xciv, 2438, 407.)—The petroleum area of the United States is estimated at 8850 square miles. Alabama has 50 square miles; Alaska, 500; California, 850; Colorado, 200; Idaho, 10; Illinois, 200; Indiana, 1000; Kansas, 200; Kentucky, 400; Louisiana, 60; Michigan, 80; Missouri, 30; New Mexico, 80; New York, 300; Ohio, 650; Oklahoma, 400; Pennsylvania, 2000; Tennessee, 80; Texas, 400; Utah, 40; West Virginia, 570; and Wyoming, 750 square miles.

A New, Cheap White Metal Alloy. ANON. (*Brass World,* viii, 12, 435.)—This new alloy, containing a large proportion of iron, has been patented by John F. Duke, of Manchester, England, in U. S. Patent 1,044,761 of 1912. The proportions are: iron, 50.30 per cent.; nickel, 19.16; copper, 29.14, and aluminum, 1.40 per cent. It is white, non-corrosive, and resists the action of vegetable acids and the atmosphere well. If more hardness is desired, add from 1 to 2 per cent. of tin.

Supposed Loss of Nitrogen in Calcium Cyanamide (Nitrolim). G. LIBERI. (*Ann. R. Staz. Chim. Agrar. Sperim. di Roma,* v, 163.)—Experiments were made to settle the conflicting statements as to the loss of nitrogen from crude calcium cyanamide on keeping, such loss being ascertained by determining the actual ammonia evolved. It was found that under the most severe conditions, such as exposure for 50 days in a constantly-changing atmosphere, saturated with water vapor, the loss of nitrogen only amounted to 3.06 per cent. of the total nitrogen in the original material. Considering the severity of the conditions, the author concludes that in practice, when the material is usually in sacks or similar containers, so that relatively a much smaller surface is exposed, and the conditions are less severe, the loss of nitrogen is practically negligible, especially if the fertilizer be kept in a dry atmosphere.

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